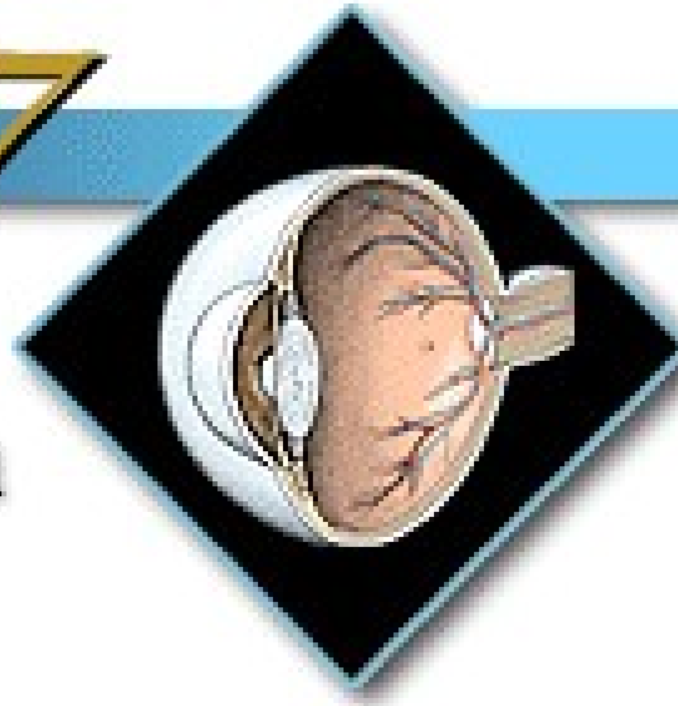
CHAPTER 17

Sensory Function



The Ear

External Ear

- **Auricle** (Pinna) - outer funnel-like structure.
- **External auditory meatus** - S-shaped tube, leads into the temporal bone.

External Ear

- **Ceruminous glands** - modified sweat glands which secrete cerumen (earwax) into external auditory meatus
- Function -It forms a sticky surface that traps small particles and keeps them from touching the eardrum.

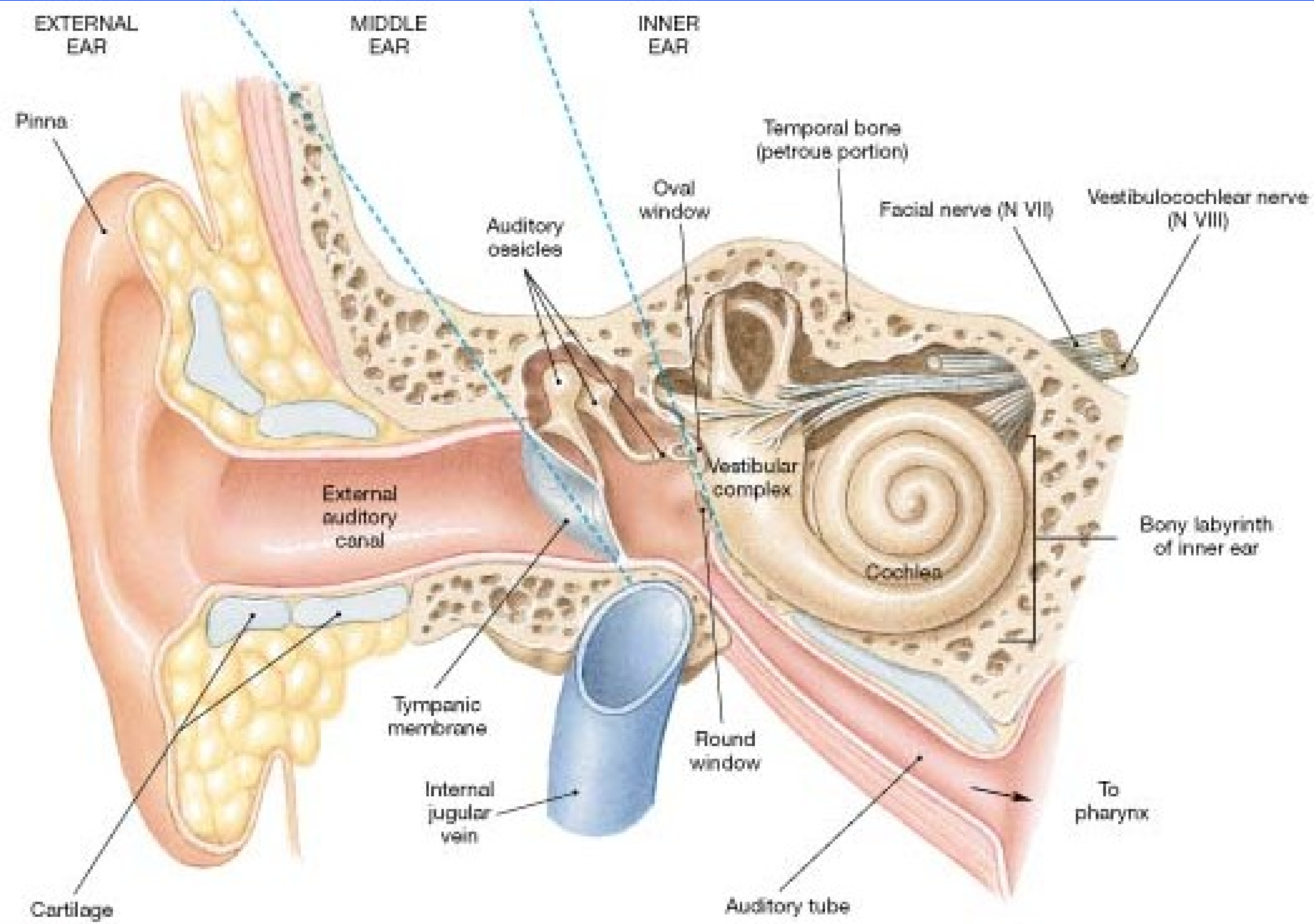


FIGURE 17-23 Anatomy of the Ear. The orientation of the external, middle, and inner ears.

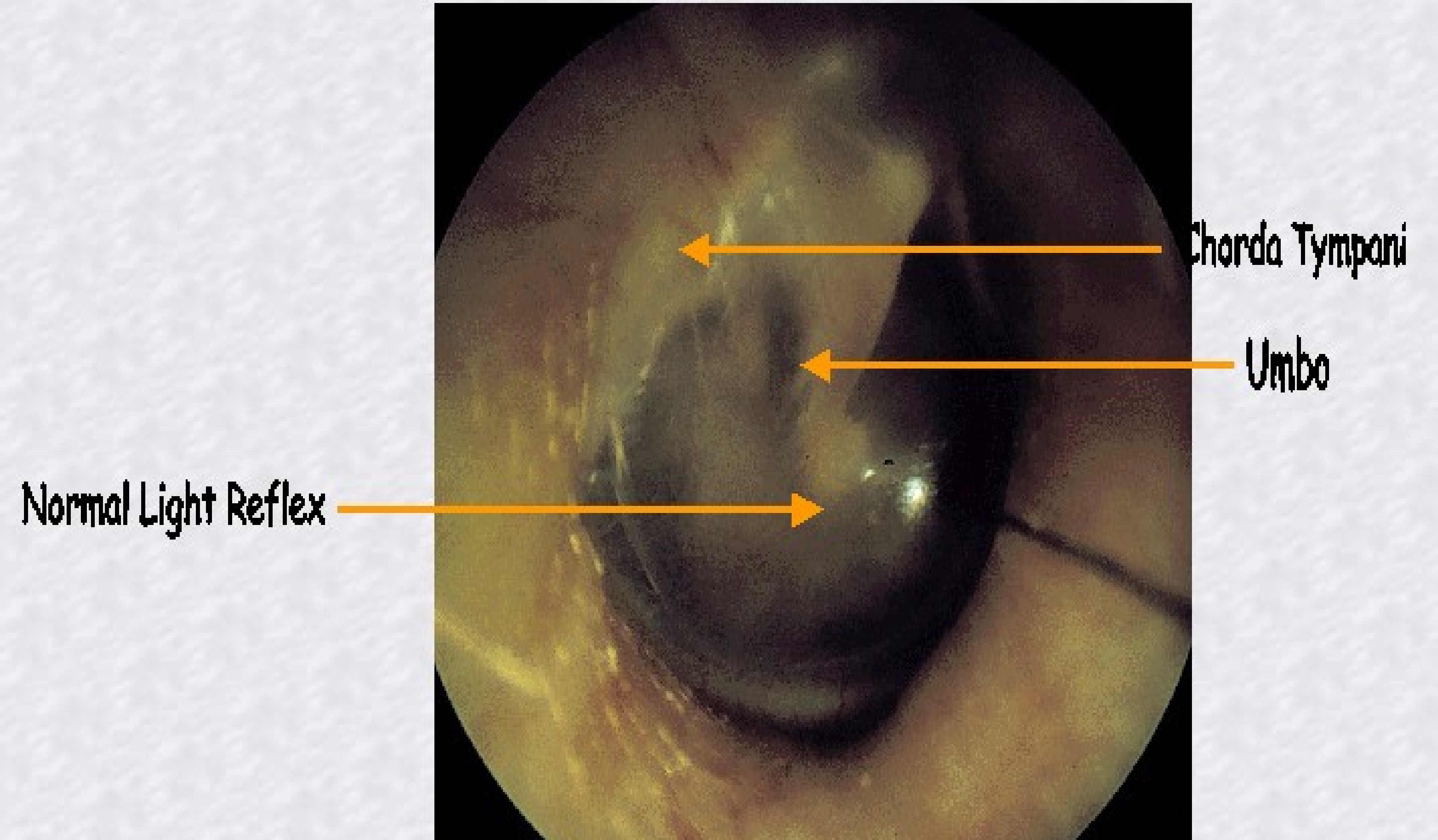
External Ear

- Function - collects sound waves created by vibrating objects

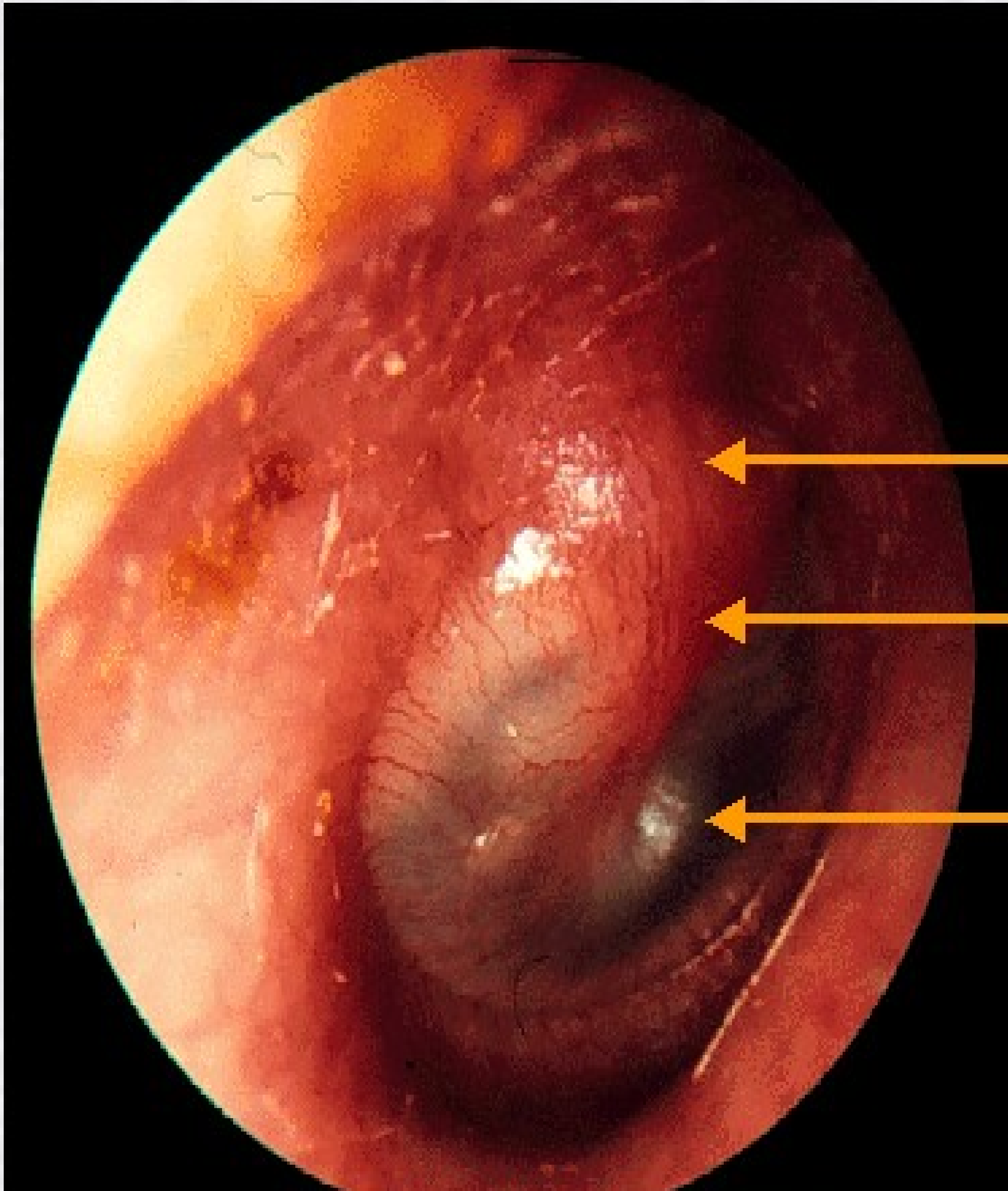
Middle Ear

- **Tympanic cavity** - air-filled space within temporal bone.
- Function - amplify sound waves and transfer energy into middle ear.

Normal Tympanic Membrane



1. Acute otitis media



Middle Ear

- **Tympanic membrane** - Semi-transparent membrane (ear drum) covered by skin on its outer surface and mucus membrane on the inner surface.
- Inner portion connected to the auditory ossicles.

Auditory Ossicles

- Malleus - a bone connected to the tympanic membrane
- Incus - middle bone connected to the malleus and the stapes
- Stapes - tiny bone connected to the incus and the oval window

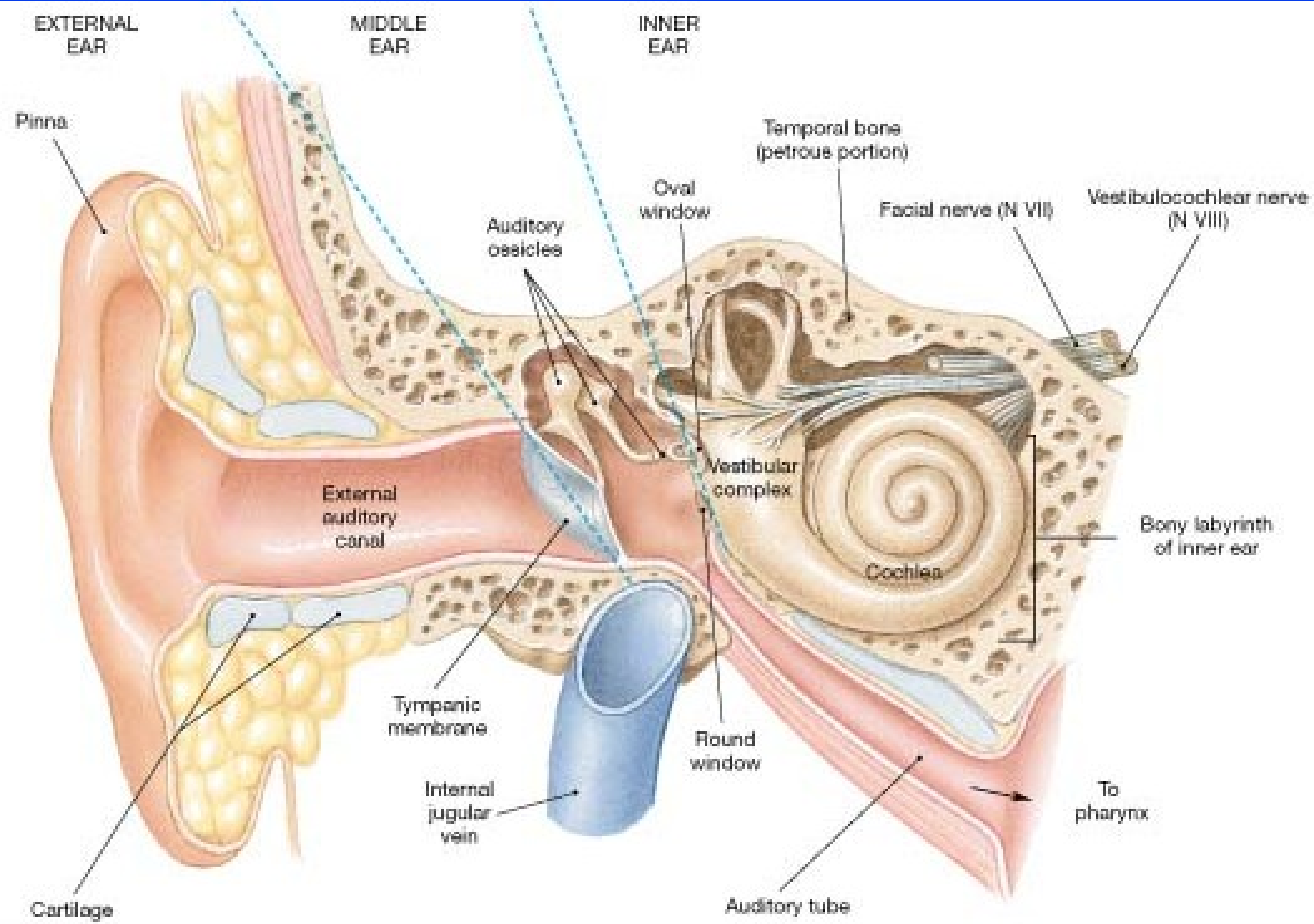
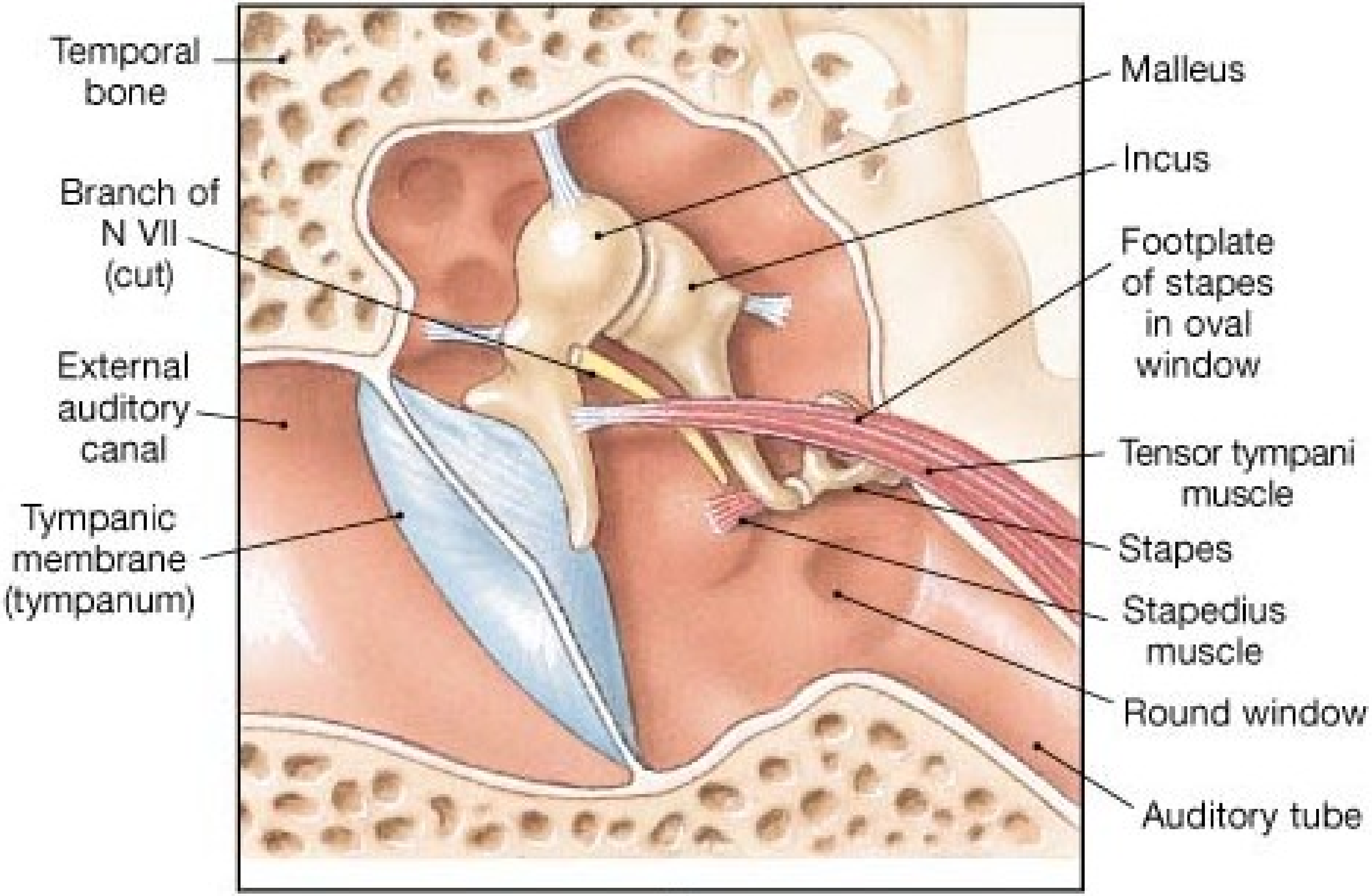


FIGURE 17-23 Anatomy of the Ear. The orientation of the external, middle, and inner ears.



(a)

FIGURE 17-24 The Middle Ear. **(a)** Detail of the structures of the middle ear.

Auditory Ossicles

- Function - Conduct sound waves from the tympanic membrane to the oval window of the inner ear.
- Help to increase (amplify) the force of vibrations as they are passed from eardrum to the oval window.

Oval Window

- Structure - membrane covered opening in the wall of the tympanic cavity.
- Function - helps to convert the vibrations into fluid-like waves within the inner ear.

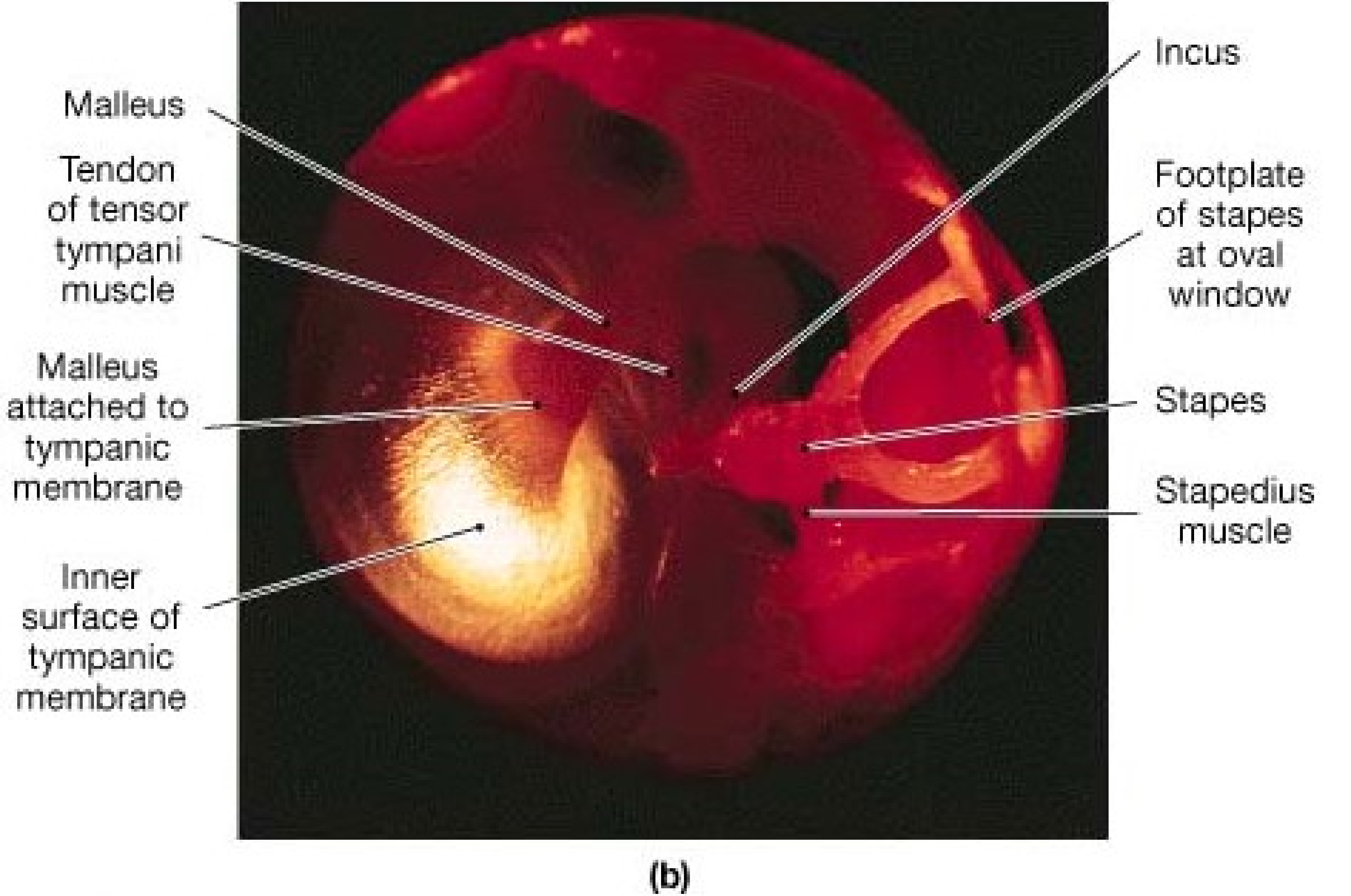


FIGURE 17-24 **The Middle Ear.** **(b)** Tympanic membrane and auditory ossicles.

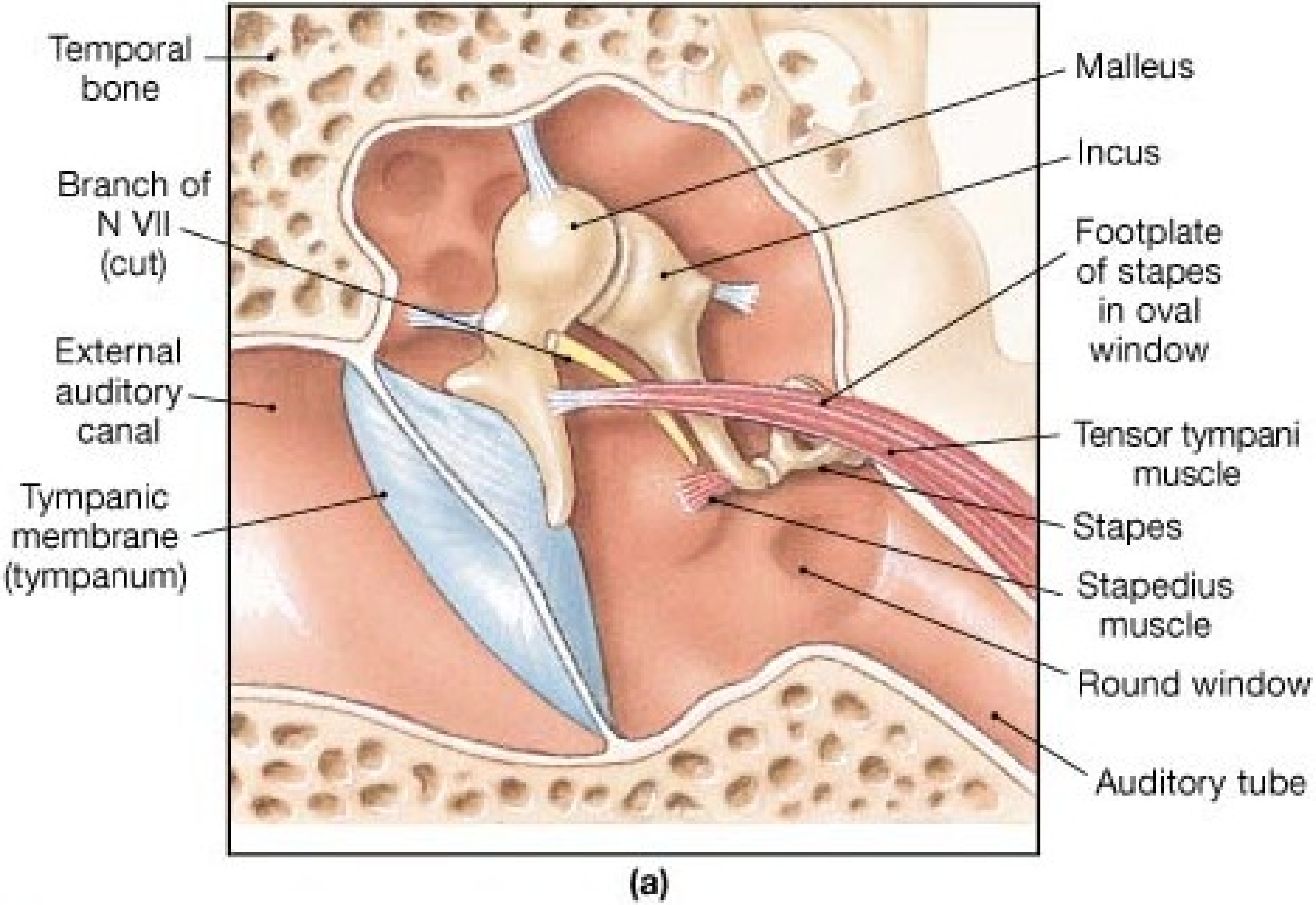


FIGURE 17-24 **The Middle Ear.** **(a)** Detail of the structures of the middle ear.

Auditory tube (*Eustachian* tube)

- A passageway that connects middle ear to the nasopharynx.
- Function - to help maintain equal air pressure on both sides of the tympanic membrane.

External Ear

- Function - transmit vibrations to the auditory ossicles.

QUESTION?

- What makes your ears pop when flying?
- When the Eustachian tube releases pressure from the middle ear the eardrum snaps back into its resting position and that movement causes the ossicles to move.

Blanance

Inner Ear

- Complex system of fluid filled intercommunicating chambers of bone (**labyrinth**).

Inner Ear

- **Semicircular canals**
  - Three fluid-filled canals in the temporal bone
  - **Ampulla** - an enlargement at one end of each semicircular canal
- Function - provide a sense of rotational equilibrium.

Inner Ear

- **Vestibule** - bony chamber between the semicircular canals and cochlea
- Contribute to both hearing and equilibrium (balance).

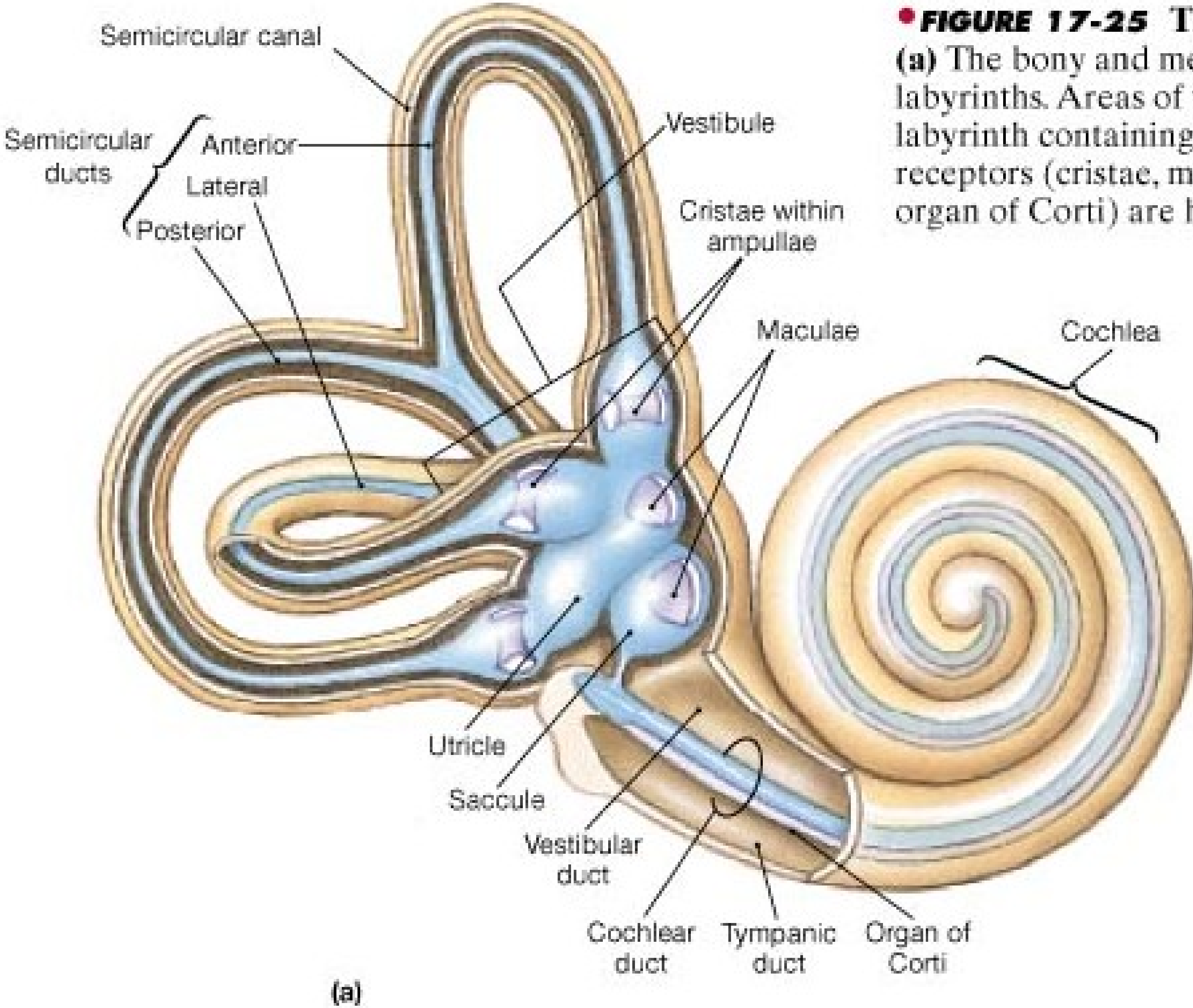


FIGURE 17-25 The Inner Ear. **(a)** The bony and membranous labyrinths. Areas of the membranous labyrinth containing sensory receptors (cristae, maculae, and the organ of Corti) are highlighted.

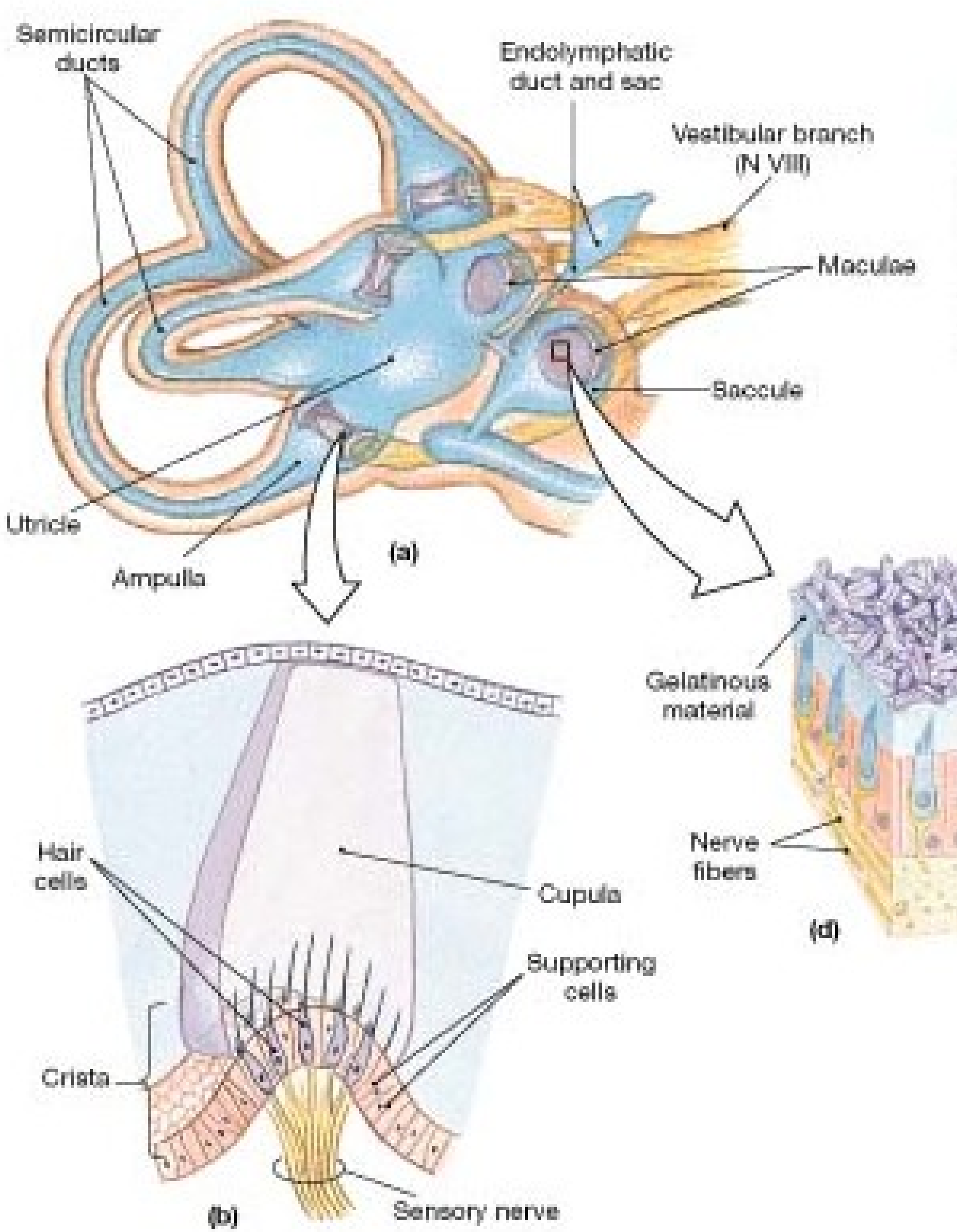


FIGURE 17-26 The Vestibular Complex. **(a)** Anterior view of the right semicircular ducts, utricle, and saccule, showing the locations of sensory receptors. **(b)** Cross section through the ampulla of a semicircular duct. **(d)** Structure of a macula.

FIGURE 17-26
The Vestibular Complex.
(e) Diagrammatic view of macular function when the head is tilted back.

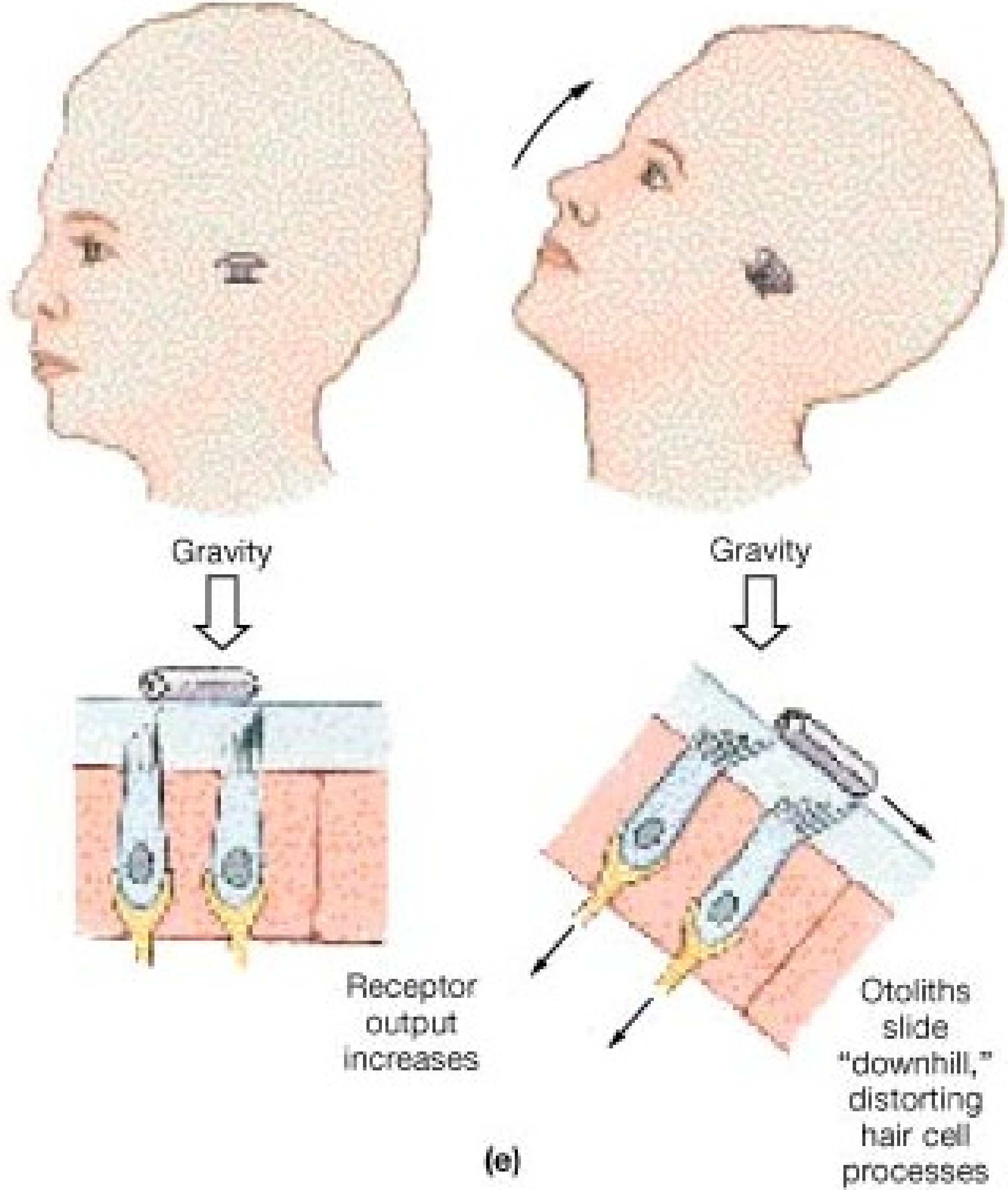
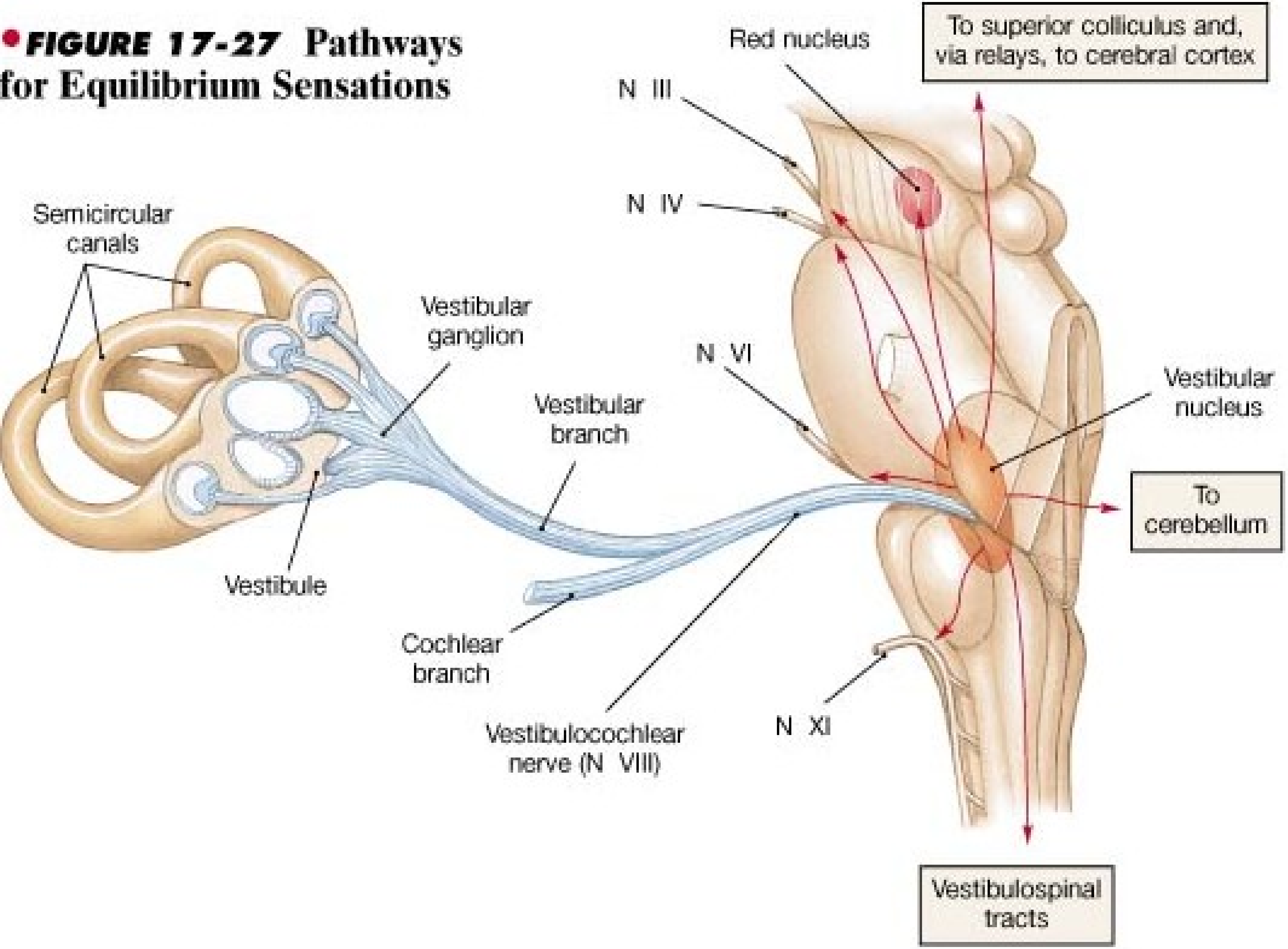


FIGURE 17-27 Pathways for Equilibrium Sensations



Sound & Hearing

Inner Ear

- **Cochlea** - snail-shaped structure
- Function - houses the organ of hearing.

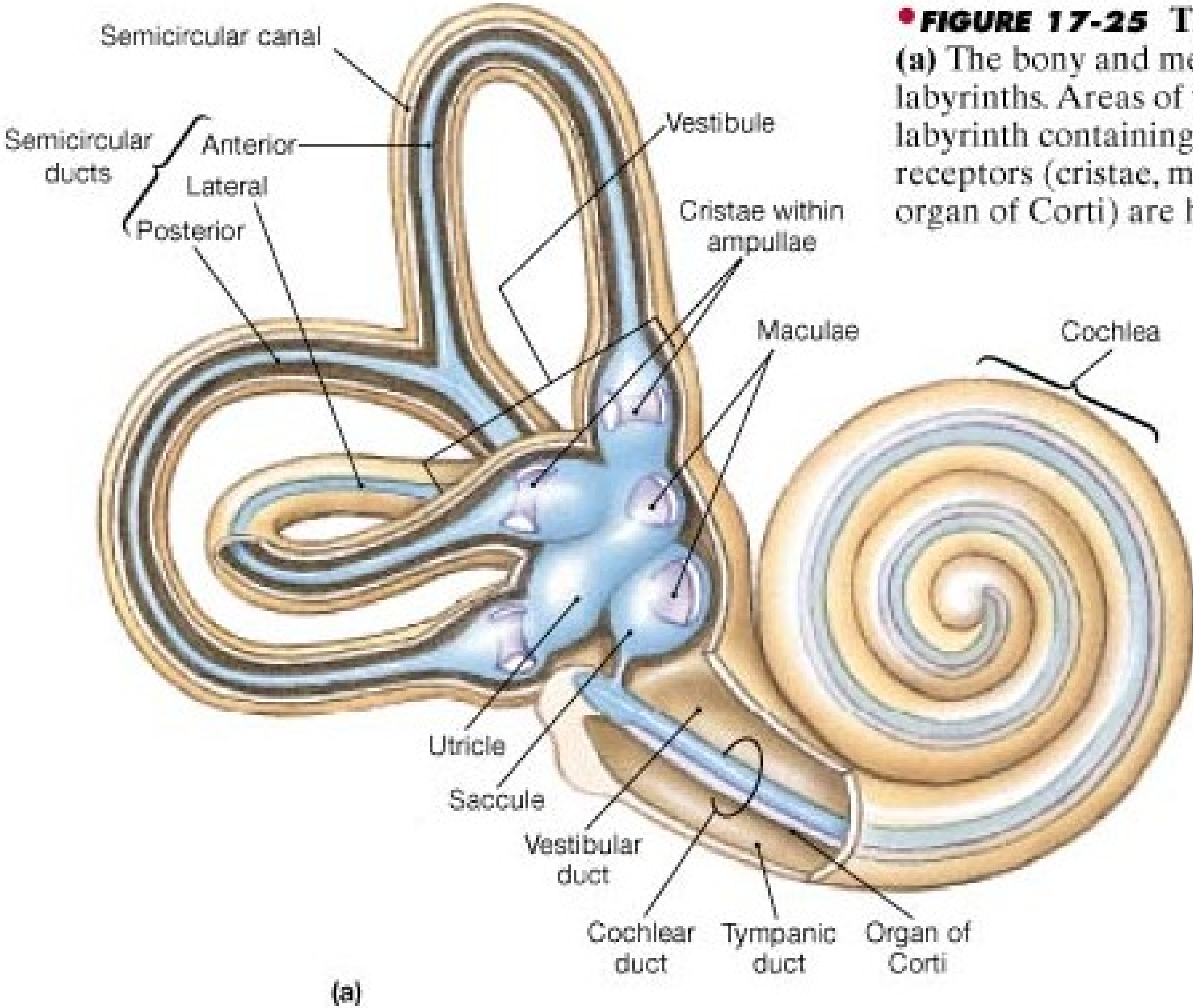
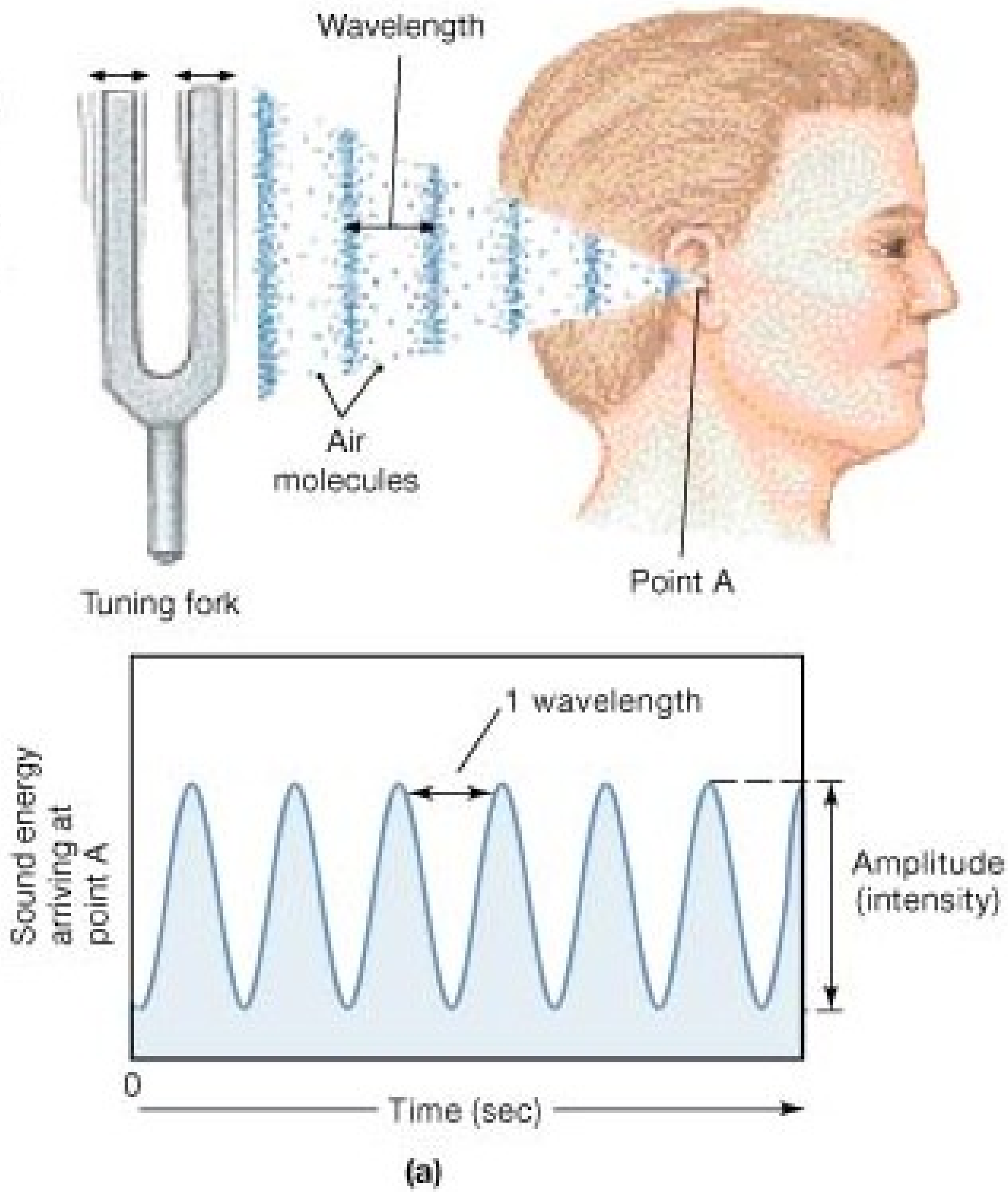
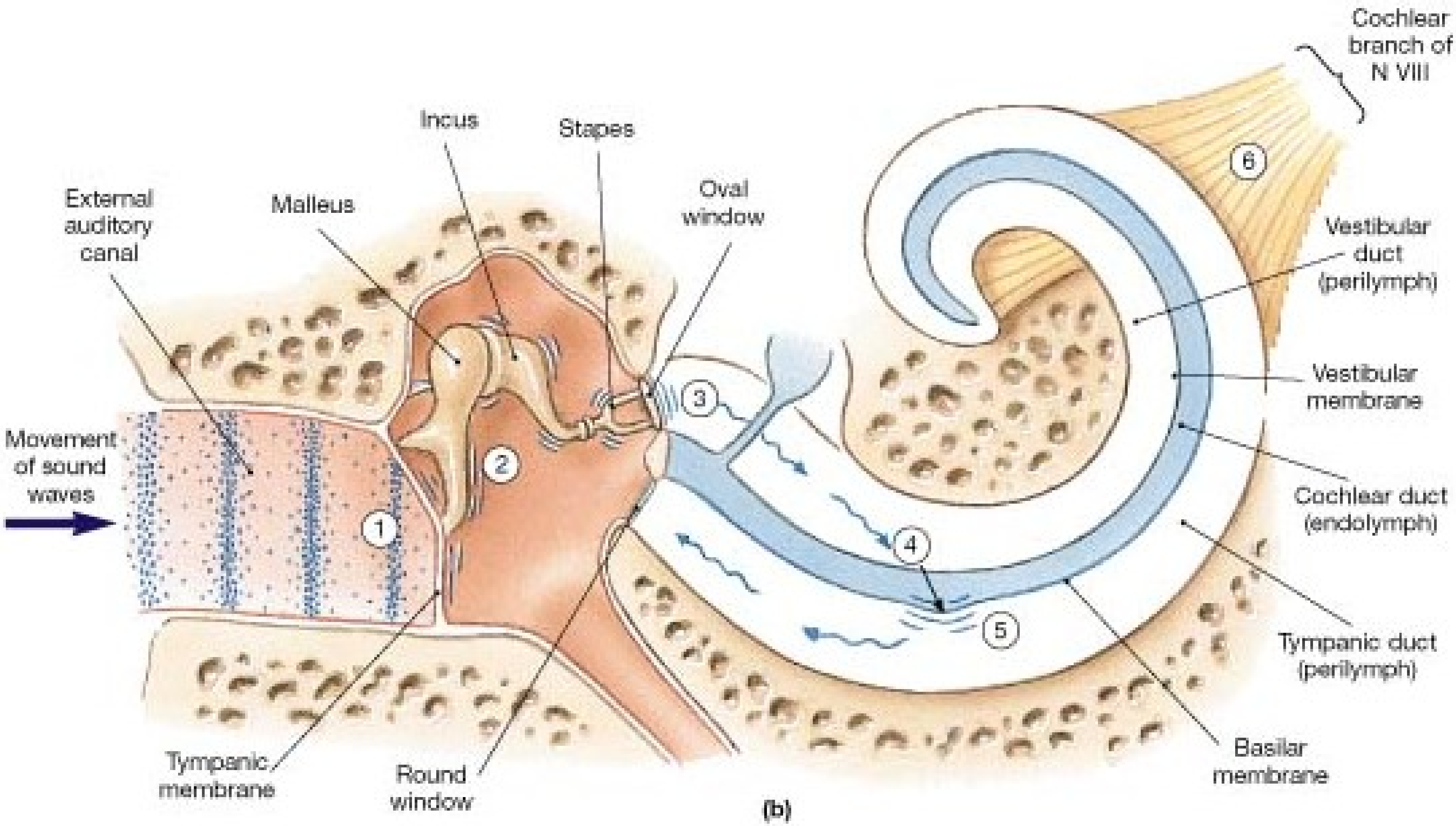


FIGURE 17-25 The Inner Ear. **(a)** The bony and membranous labyrinths. Areas of the membranous labyrinth containing sensory receptors (cristae, maculae, and the organ of Corti) are highlighted.

FIGURE 17-29 Sound and Hearing. **(a)** Sound waves generated by a tuning fork travel through the air as pressure waves. The frequency of the sound wave is the number of wavelengths that pass a fixed reference point each second. Frequencies are reported in terms of cycles per second (cps), or hertz (Hz).





•***FIGURE 17-29*** **Sound and Hearing.** **(b)** Steps in the reception and transduction of sound energy. ***Step 1.*** Sound waves arrive at typmanic membrane. ***Step 2.*** Displacement of auditory ossicles. ***Step 3.*** Pressure waves in the perilymph of the vestibular duct. ***Step 4.*** Pressure waves distort basilar membrane. ***Step 5.*** Vibration of hair cells against the tectorial membrane. ***Step 6.*** Information about region and intensity of stimulation relayed to CNS.

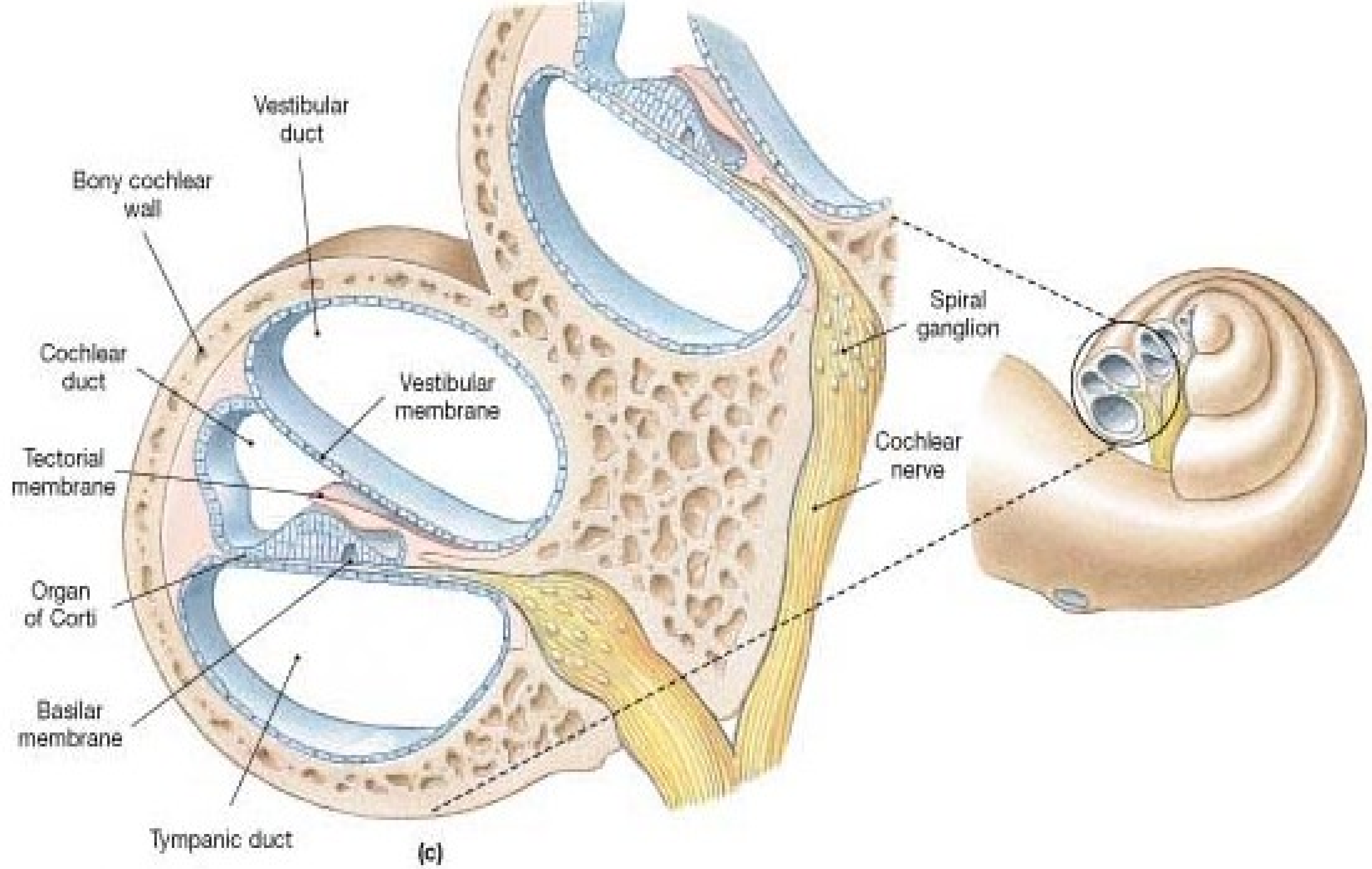
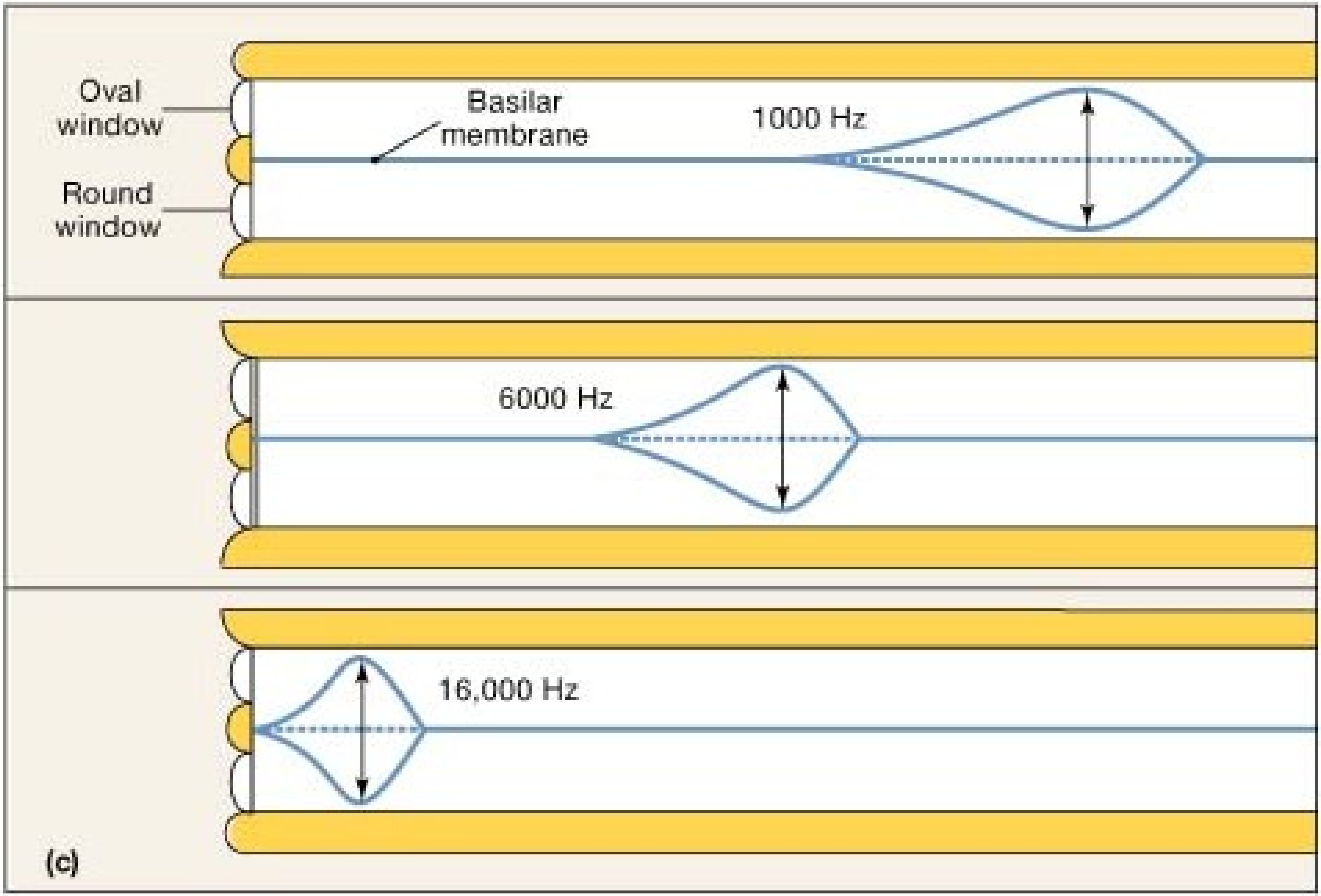
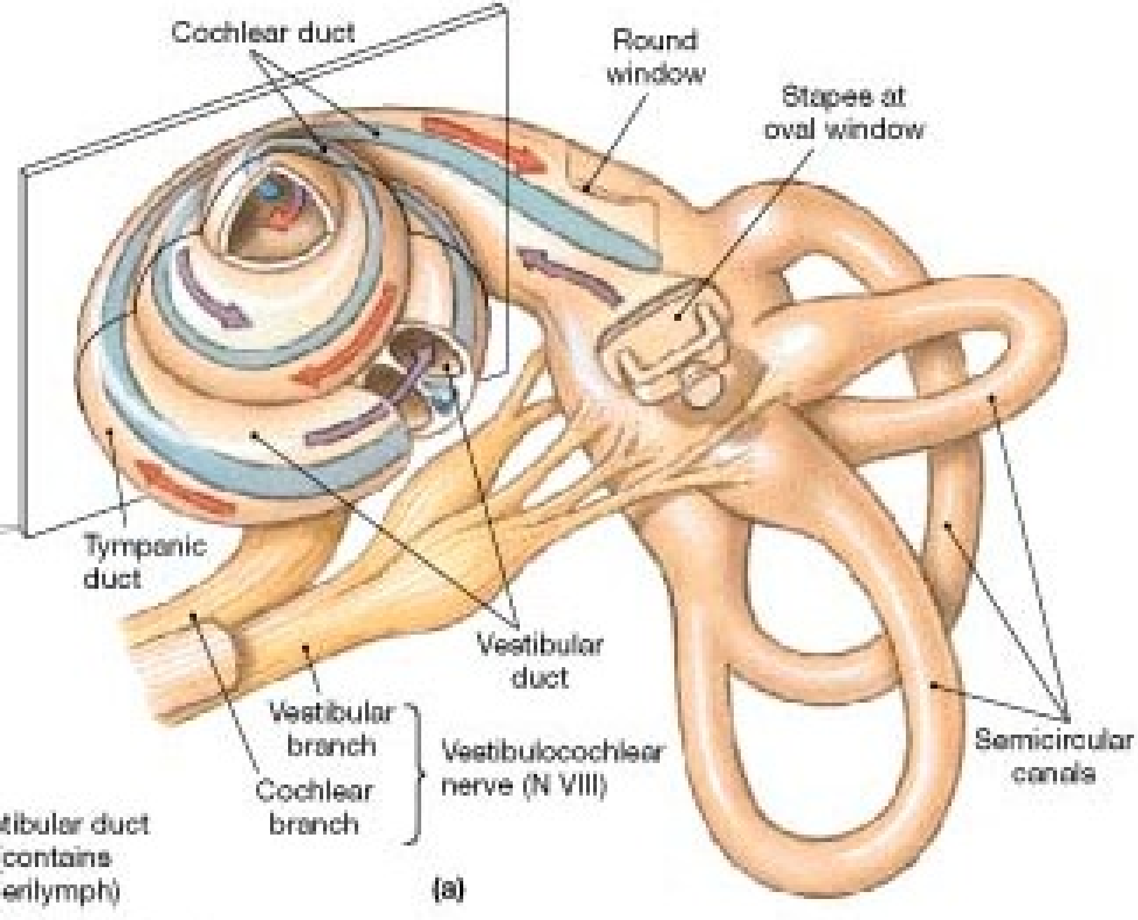


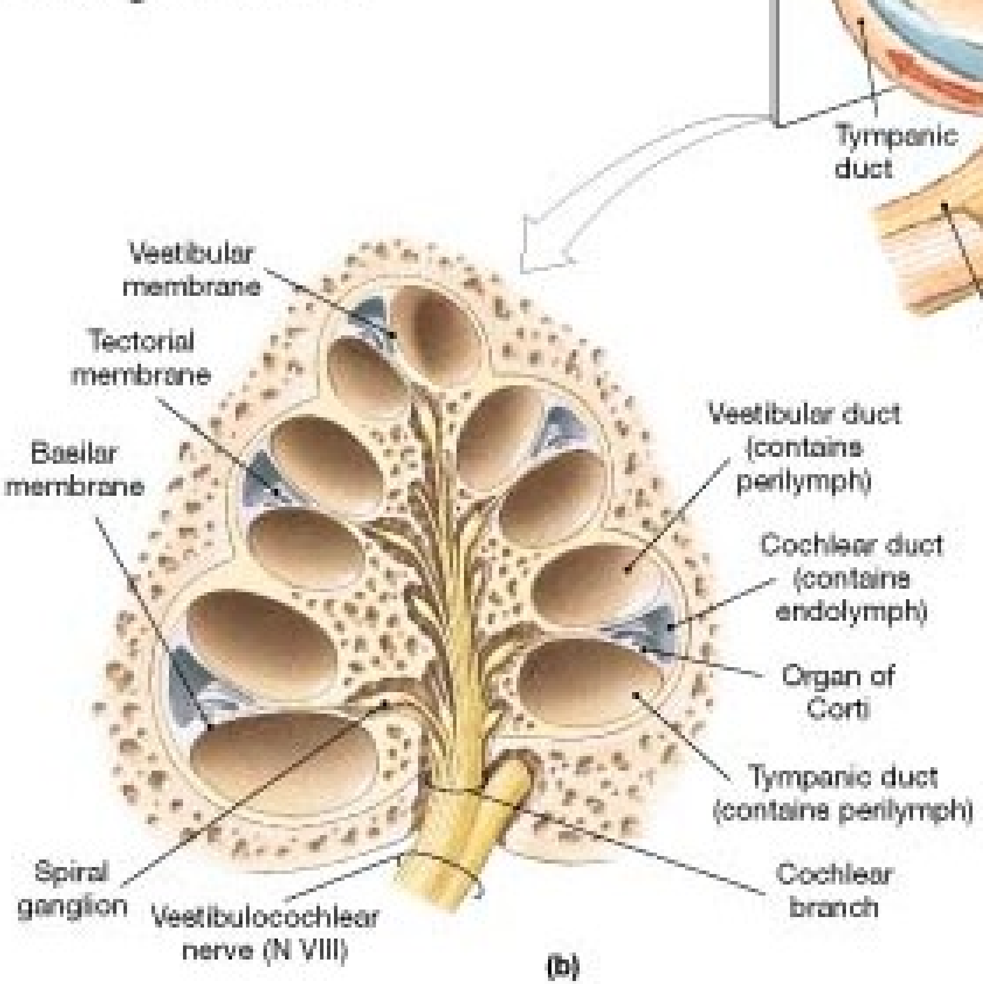
FIGURE 17-28 The Cochlea. (c) Three-dimensional section showing details of the compartments, tectorial membrane, and organ of Corti.

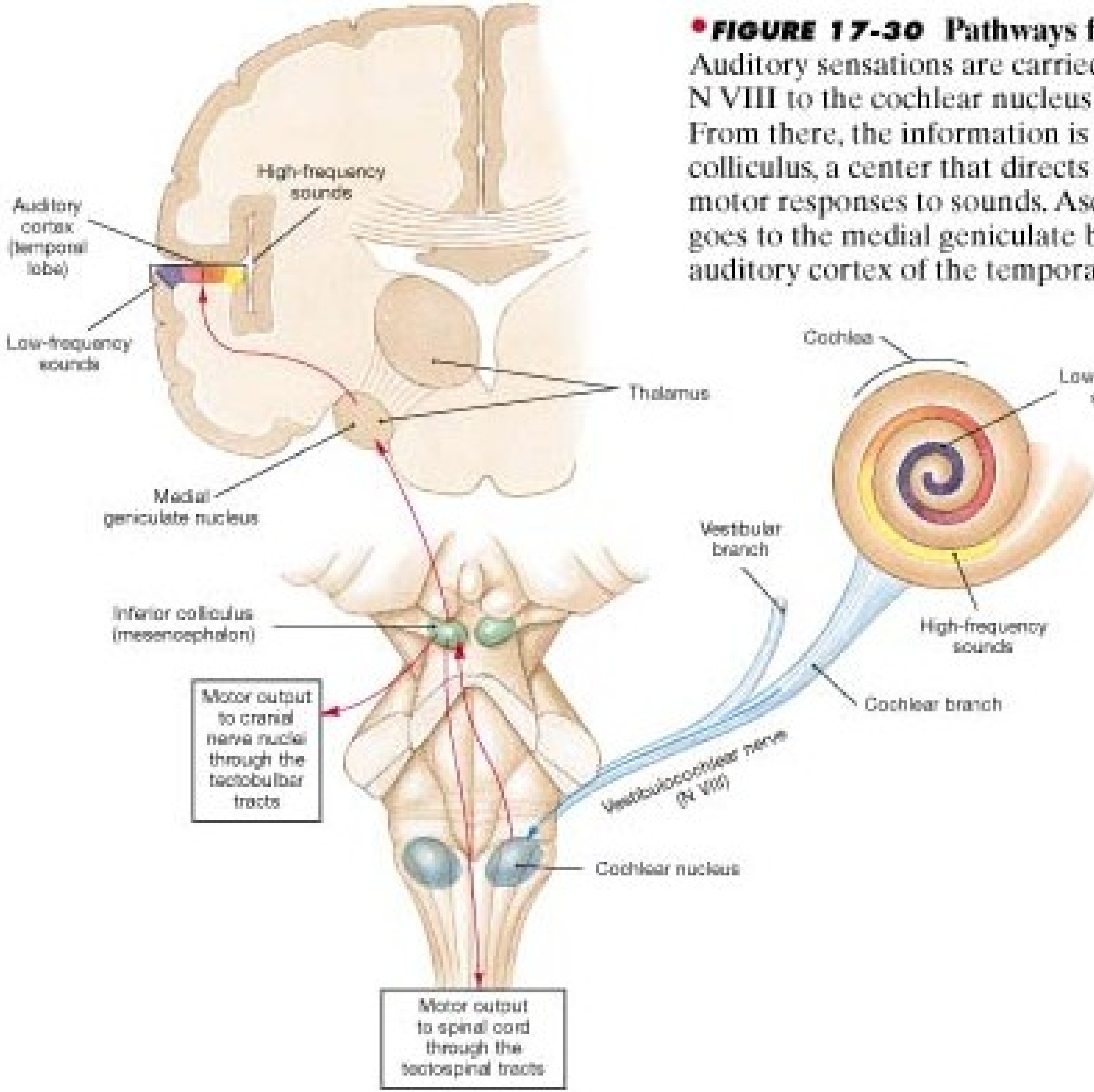


• ***FIGURE 17-29*** **Sound and Hearing.** **(c)** The location of distortion in the basilar membrane shifts toward the oval window as the frequency of the sound increases.

FIGURE 17-28 **The Cochlea.**
(a) Structure of the cochlea.
(b) Diagrammatic view of the cochlear spiral. Three-dimensional section showing details of the compartments, tectorial membrane, and organ of Corti.





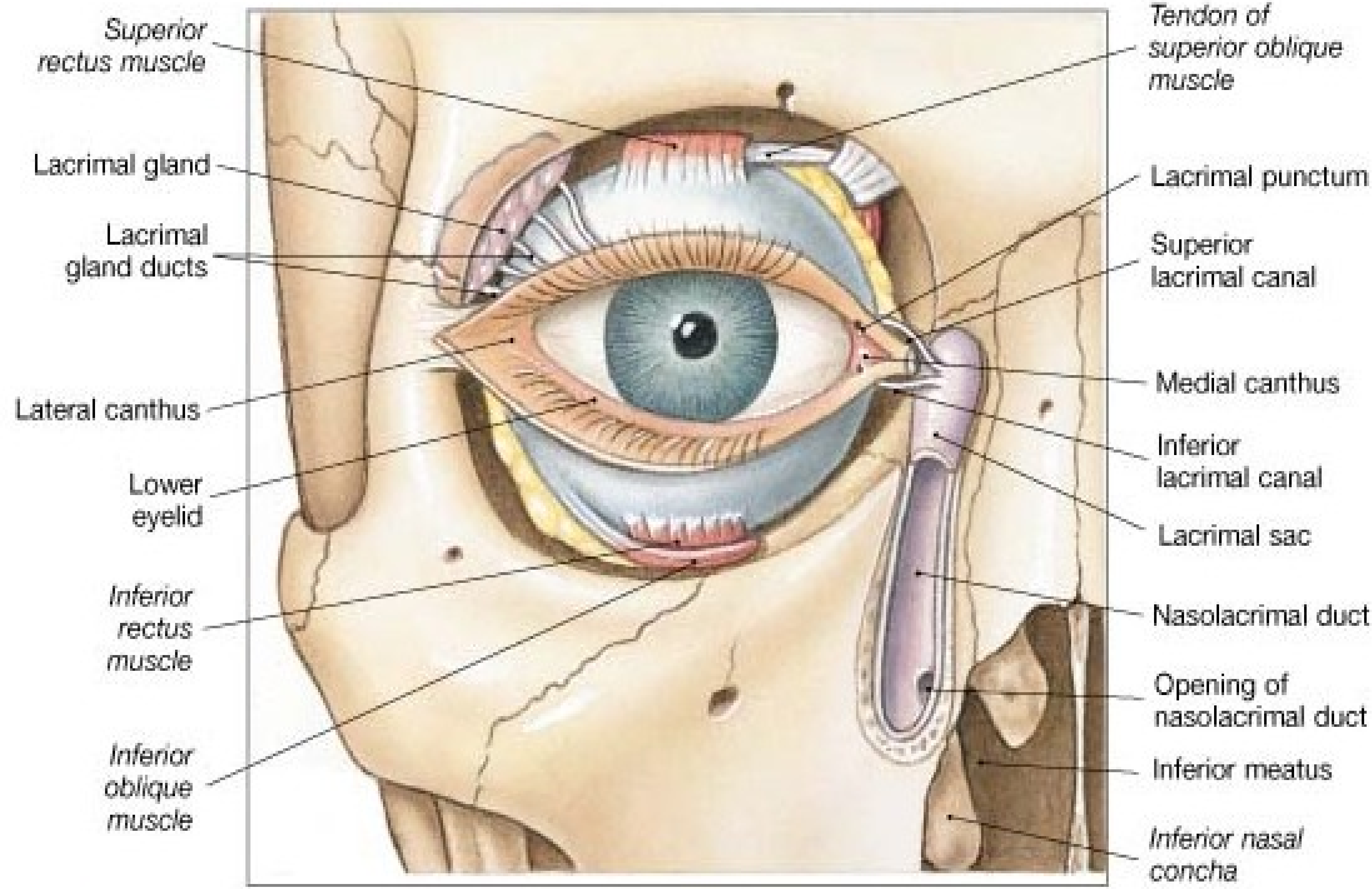


• *FIGURE 17-30* Pathways for Auditory Sensations. Auditory sensations are carried by the cochlear branch of N VIII to the cochlear nucleus of the medulla oblongata. From there, the information is relayed to the inferior colliculus, a center that directs a variety of unconscious motor responses to sounds. Ascending acoustic information goes to the medial geniculate before being forwarded to the auditory cortex of the temporal lobe.

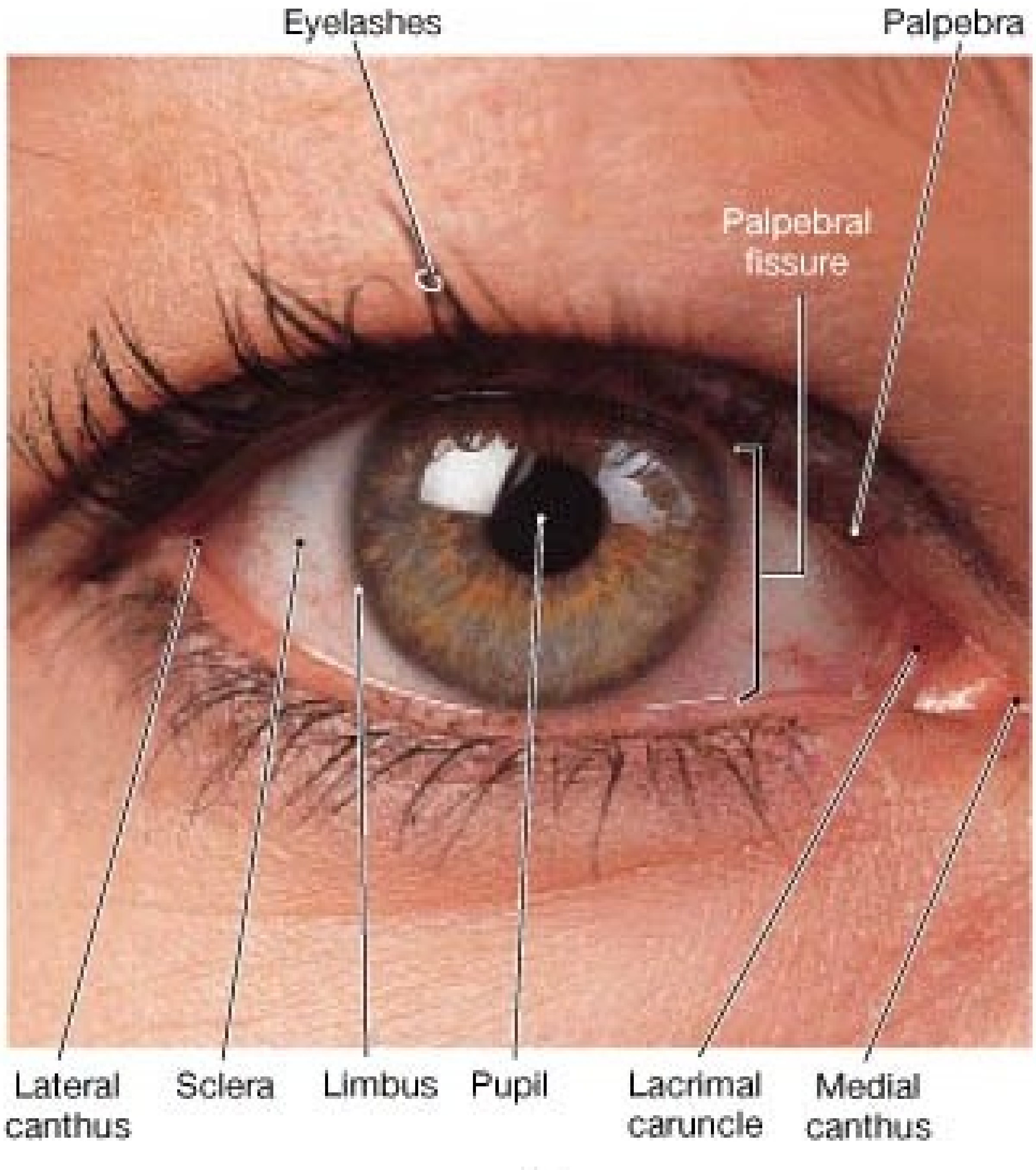
The Eye

Eye

- **Accessory organs** -
  - Eyelids
  - Conjunctiva - thin mucus membrane
  - Lacrimal apparatus - tears
  - Extrinsic muscles
- Function - Protect the outer surface of the eye & movement of the eye



• ***FIGURE 17-8*** **External Features and Accessory Structures of the Eye.** Details of the organization of the lacrimal apparatus.



• ***FIGURE 17-8*** **External Features and Accessory Structures of the Eye.** **(a)** Gross and superficial anatomy of the accessory structures.

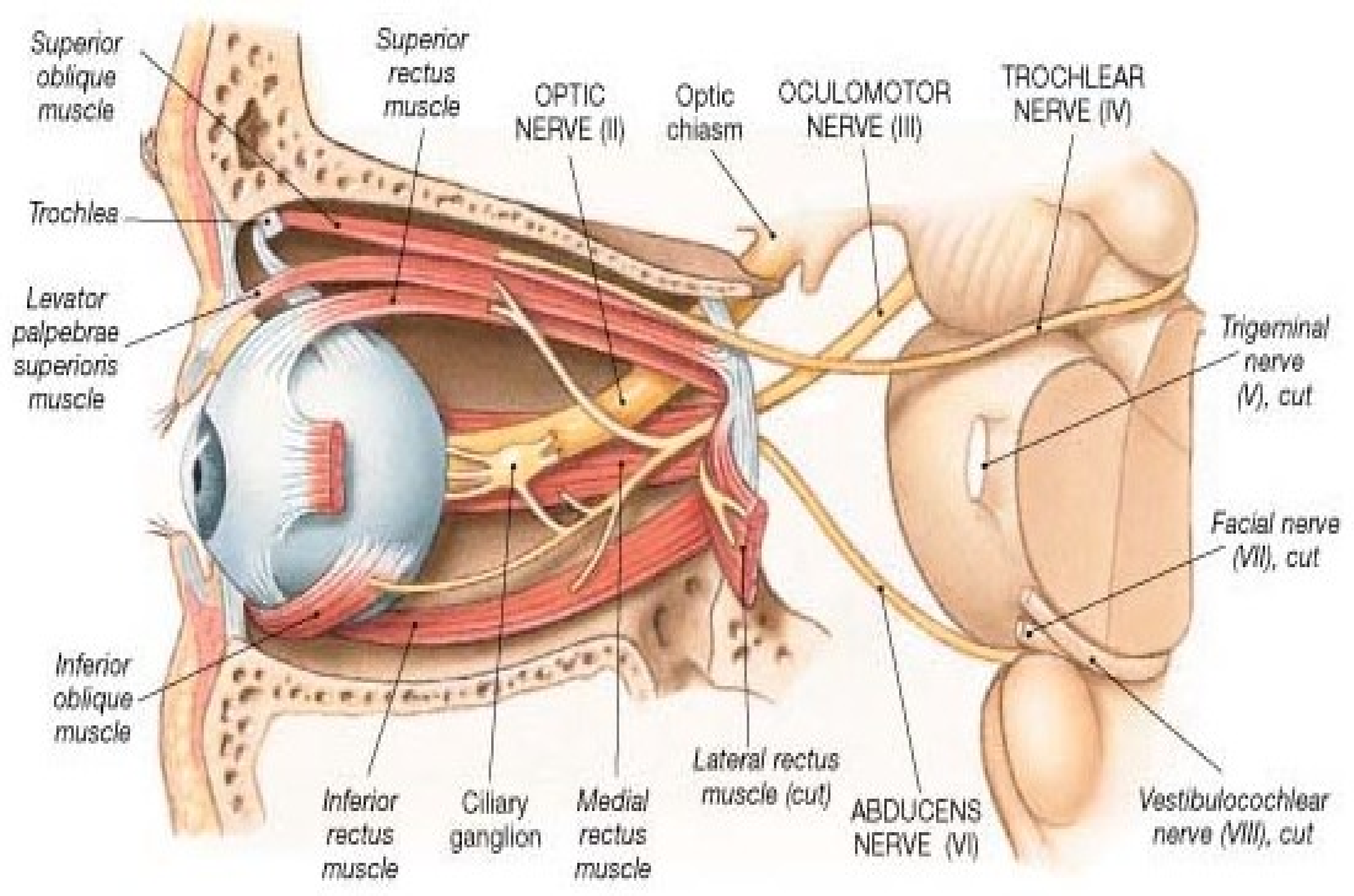


FIGURE 14-22 **Cranial Nerves Controlling the Extrinsic Eye Muscles**

Eye

- The eyeball consist of three separate and unique layers or tunics:
  - The outer layer or fibrous tunic consists of the cornea and the sclera (the “white” of the eye)
  - The middle layer or vascular tunic has three portions: choroid, ciliary body, & iris.
  - The inner layer or nervous tunic is the rentia lines the posterior 2/3.

Cornea

- Transparent connective tissue and epithelium that covers the colored iris
  - Contains relatively few cells and **no** blood vessels.
- Function
  - Serves as the window of the eye, letting light enter.
  - Helps focus entering light rays.

Corneal Transplants

- Corneal transplants are the most common organ transplants operation & the most successful type of transplant since rejections rarely occurs.
- Because the cornea is avascular, blood-borne antibodies that might cause rejection do not enter the transplanted tissue or artifical corneas.

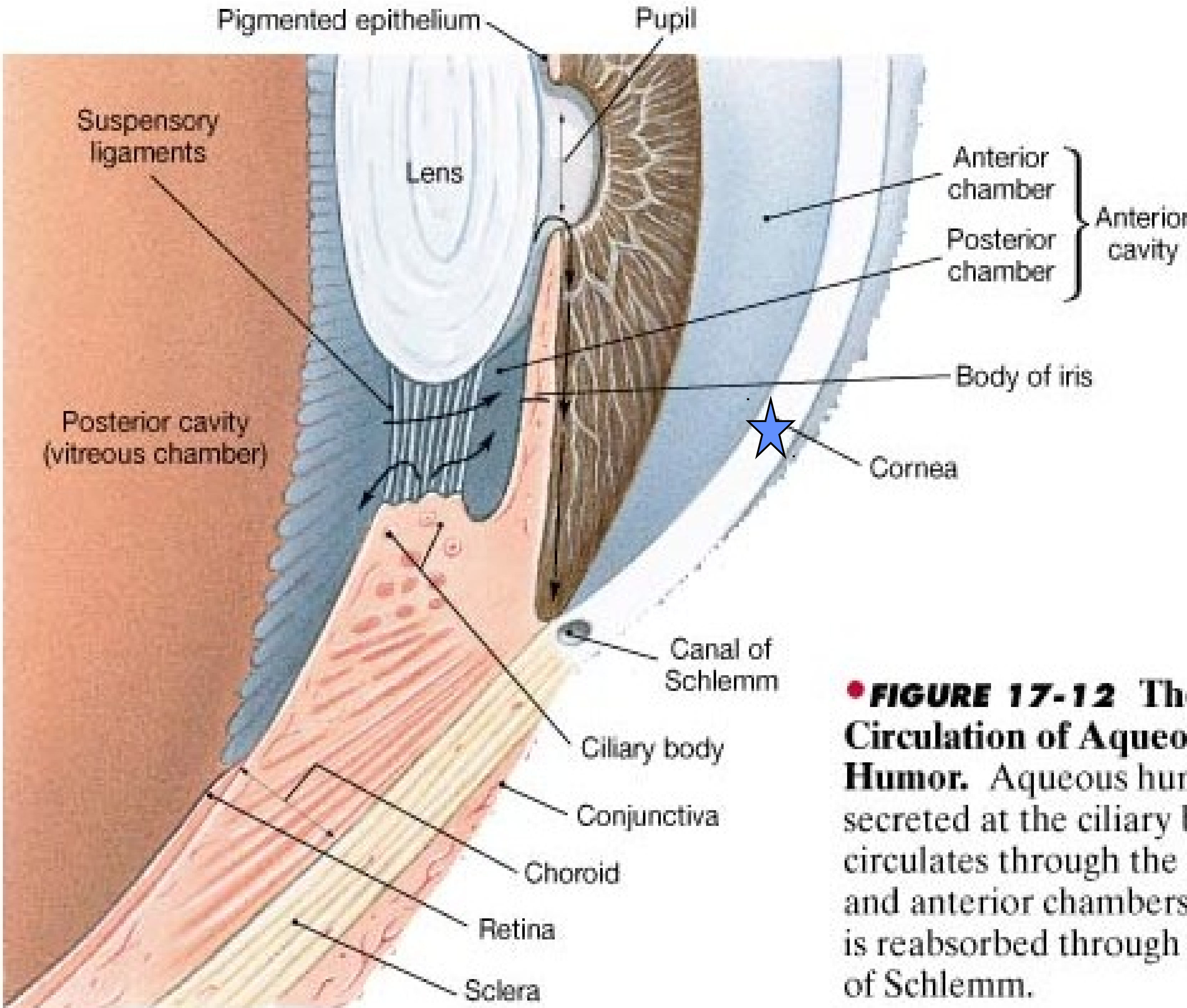


FIGURE 17-12 **The Circulation of Aqueous Humor.** Aqueous humor secreted at the ciliary body circulates through the posterior and anterior chambers before it is reabsorbed through the canal of Schlemm.

Anterior Cavity

- Between the Cornea and Iris and around Iris is a cavity which is filled with a watery fluid called aqueous humor - replace every 90 minutes.
- Function - helps nourish the lens and cornea, and accounts for the pressure of the eye, called <u>intraocular pressure</u>.
- Excess intraocular pressure is called **glaucoma** - which leads to blindness.

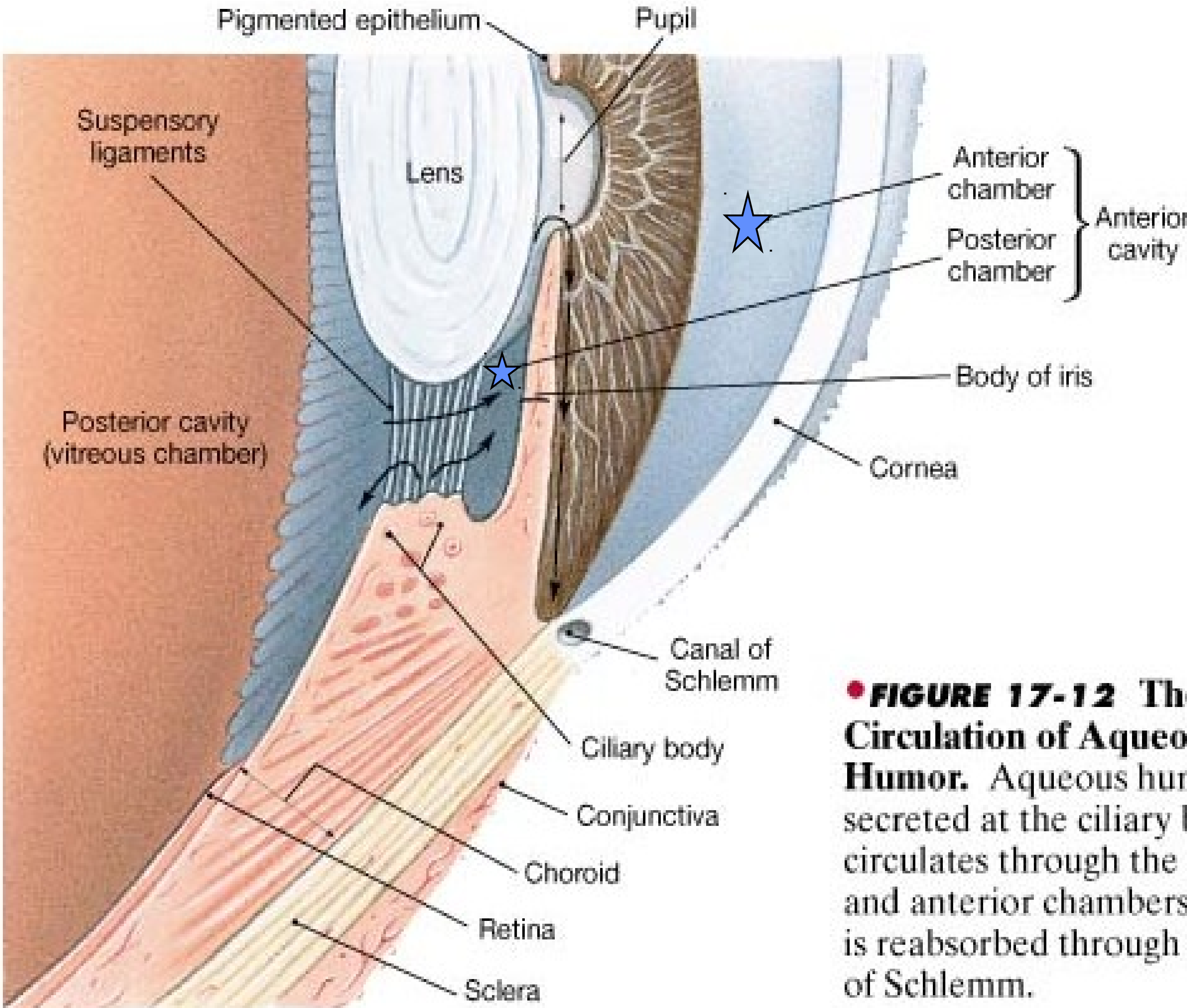


FIGURE 17-12 The Circulation of Aqueous Humor. Aqueous humor secreted at the ciliary body circulates through the posterior and anterior chambers before it is reabsorbed through the canal of Schlemm.

Sclera (white portion)

- Composed of dense connective tissues of mostly collagenous and some elastic fibers
  - Pierced by the optic nerve and blood vessels in the back.
- Function - Provides protection & serves as an attachment for the extrinsic muscles of the eye.
- It give shape to the eyeball

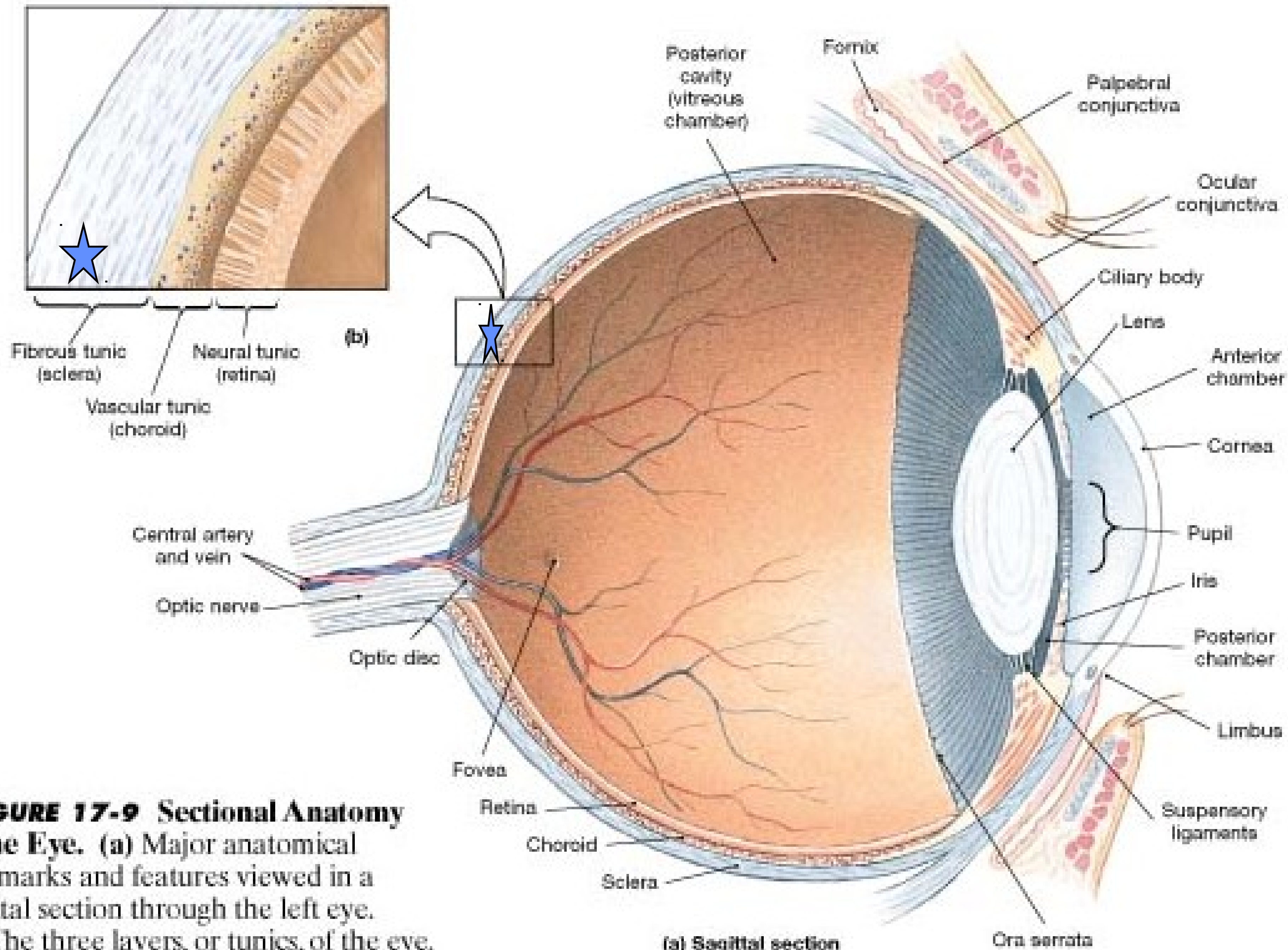


FIGURE 17-9 Sectional Anatomy of the Eye. **(a)** Major anatomical landmarks and features viewed in a sagittal section through the left eye. **(b)** The three layers, or tunics, of the eye.

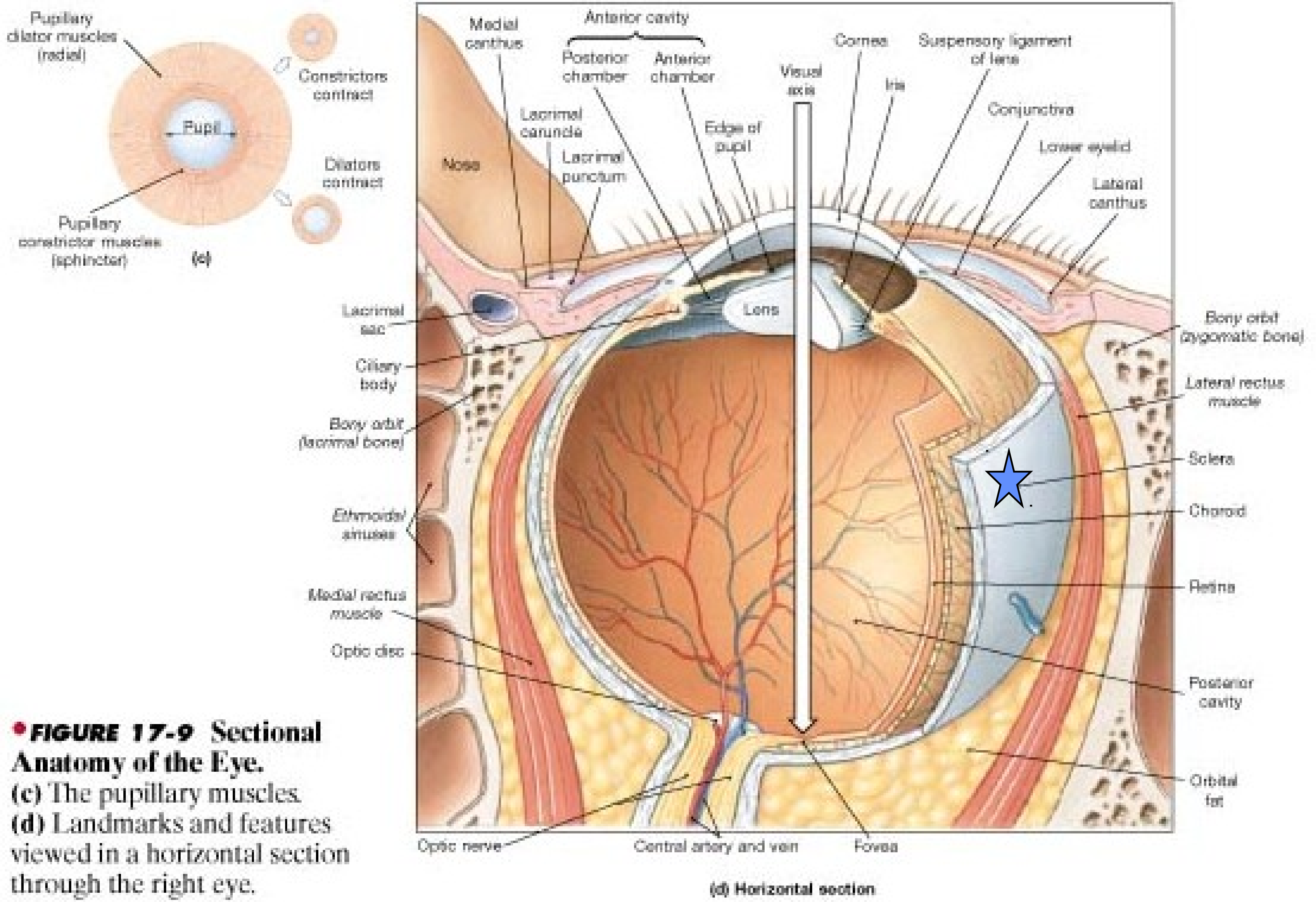
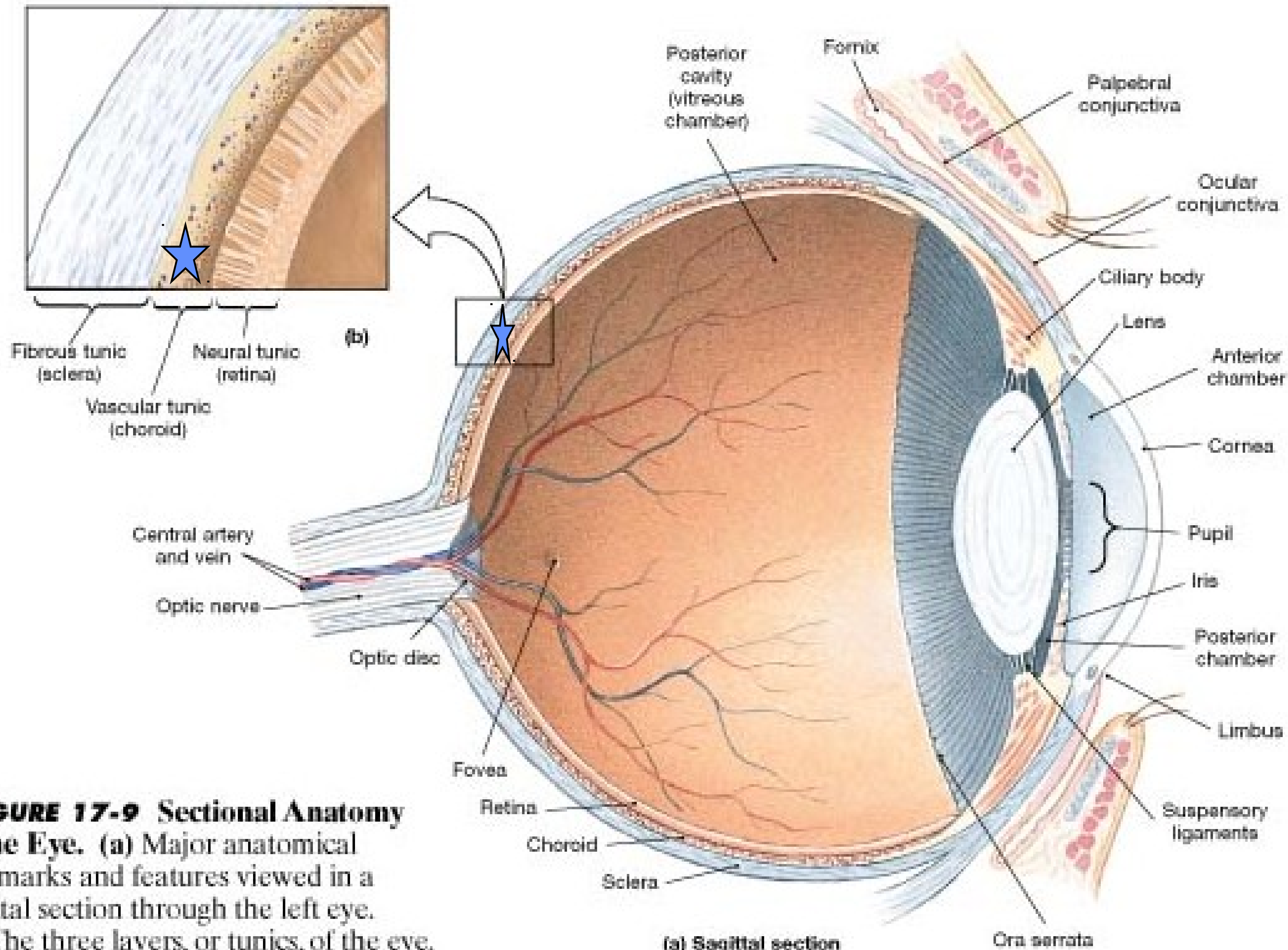


FIGURE 17-9 Sectional Anatomy of the Eye.
(c) The pupillary muscles.
(d) Landmarks and features viewed in a horizontal section through the right eye.

Middle Layer

- **Choroid coat** - is loosely joined to sclera & is rich with blood vessels.
  - Contains a dark pigment (melanin)
- Function - Absorbs excess scattered light, which prevents reflection and scattering of the light within the eyeball. This ensures that the image cast on the retina by the cornea and lens remains sharp and clear.



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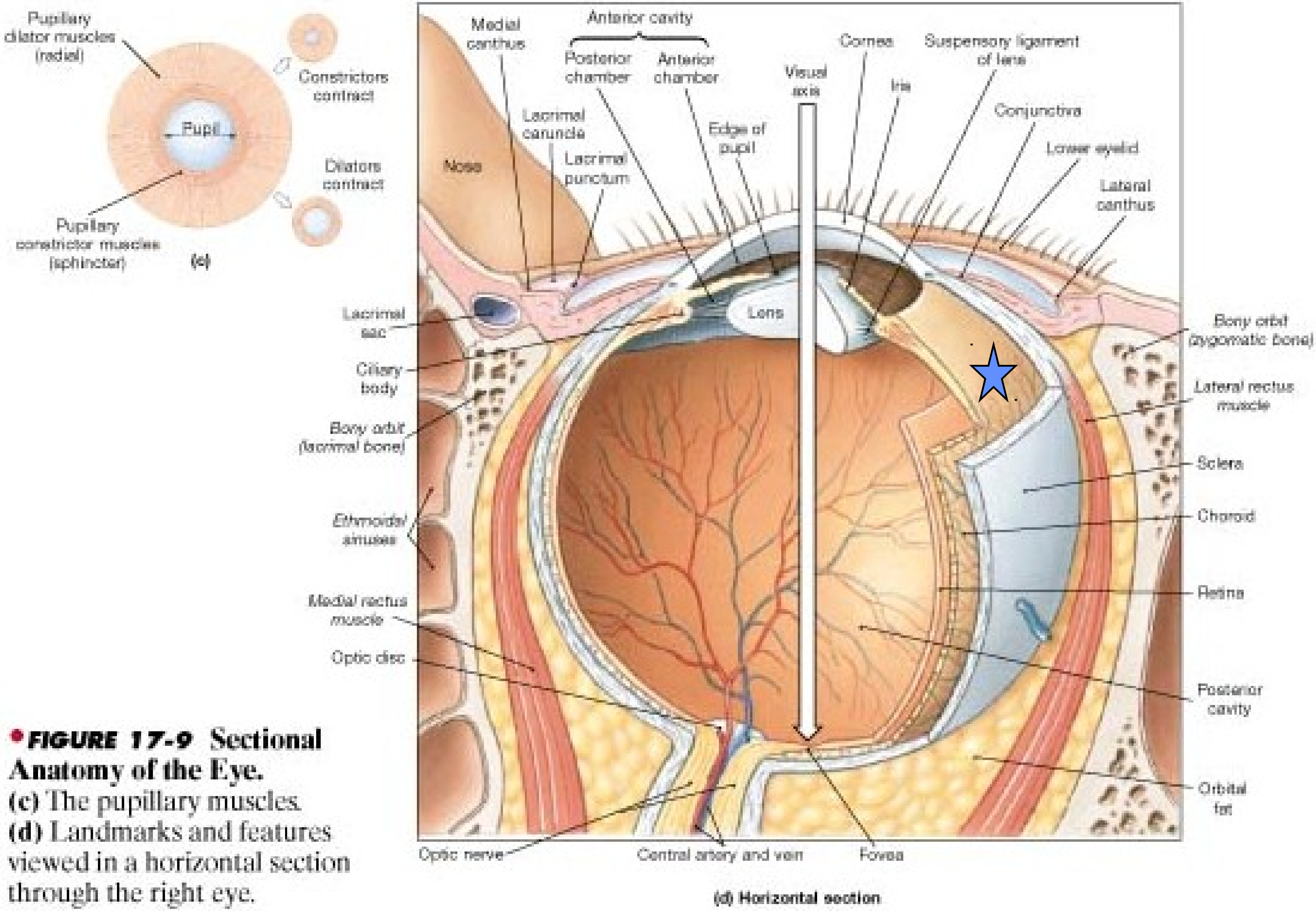


FIGURE 17-9 Sectional Anatomy of the Eye.
(c) The pupillary muscles.
(d) Landmarks and features viewed in a horizontal section through the right eye.

Middle Layer

- **Ciliary body** - Contains ciliary processes & two distinct groups of muscle fibers that constitute the ciliary muscles.
- Function - Produces liquid that fills the front part of the eyeball
  - Acts on the lens via suspensory ligaments to adjust for near and far vision.

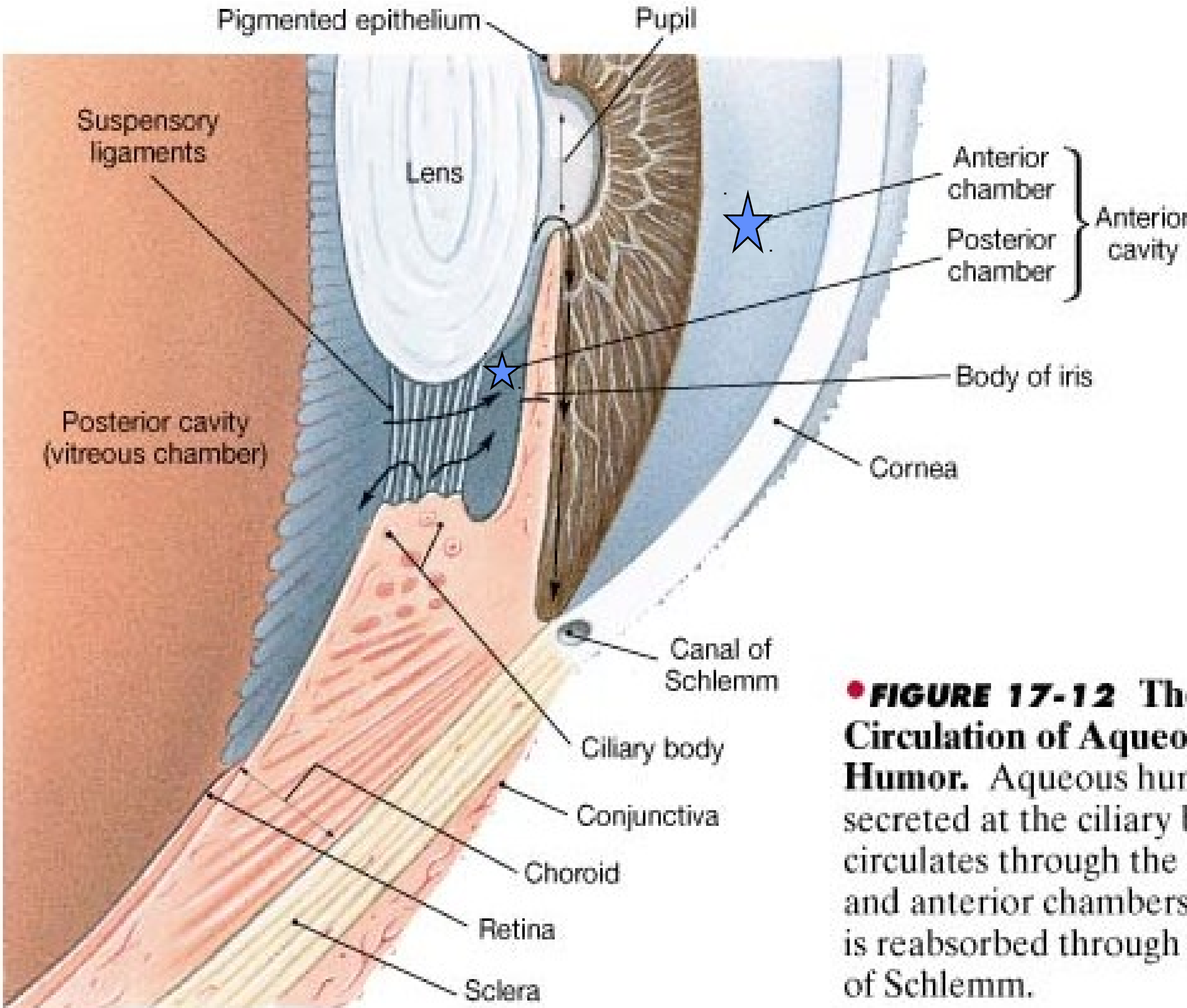


FIGURE 17-12 **The Circulation of Aqueous Humor.** Aqueous humor secreted at the ciliary body circulates through the posterior and anterior chambers before it is reabsorbed through the canal of Schlemm.

Middle Layer

- **Iris** - is the colored portions of the eye
  - it is a thin diaphragm composed largely of connective tissue and smooth muscle fibers.
  - It is suspended between the cornea & the lens & is attached at its outer margin to the ciliary processes.

Middle Layer

- **Pupil** - is the hole in the center of the iris through which light passages.
- Smooth muscle fibers of the iris are arranged into two groups, circular and radial muscles
- Function - to regulate the amount of light by controlling the size of the pupil

Inner Layer

- **Retina** - contains the visual receptor cells, nerve cells, & blood vessels.
- It is a nearly transparent sheet of tissue that is continuous with the optic nerve.
- Here blood vessels can be viewed directly & examined for pathological changes such as occur with hypertension or diabetes.

Retina

- Function - converts image into nerve impulses

Retina

- **Macula lutea** - the exact center of the back of the retina which contains the <u>central fovea</u>.

Retina

- **Fovea Centralis** - is a small indentation on the central area on retina (macula lutea) which contain only cone photoreceptors
- Function - area of sharpest vision and color vision.

Photoreceptors

- Each retina has about 6 million cones and 120 million rods.
- **Rods** are most important for seeing shades of gray in dim light. They also allows to see shapes and movement.
- **Cones** provide color vision in bight light - they do not function in low light.

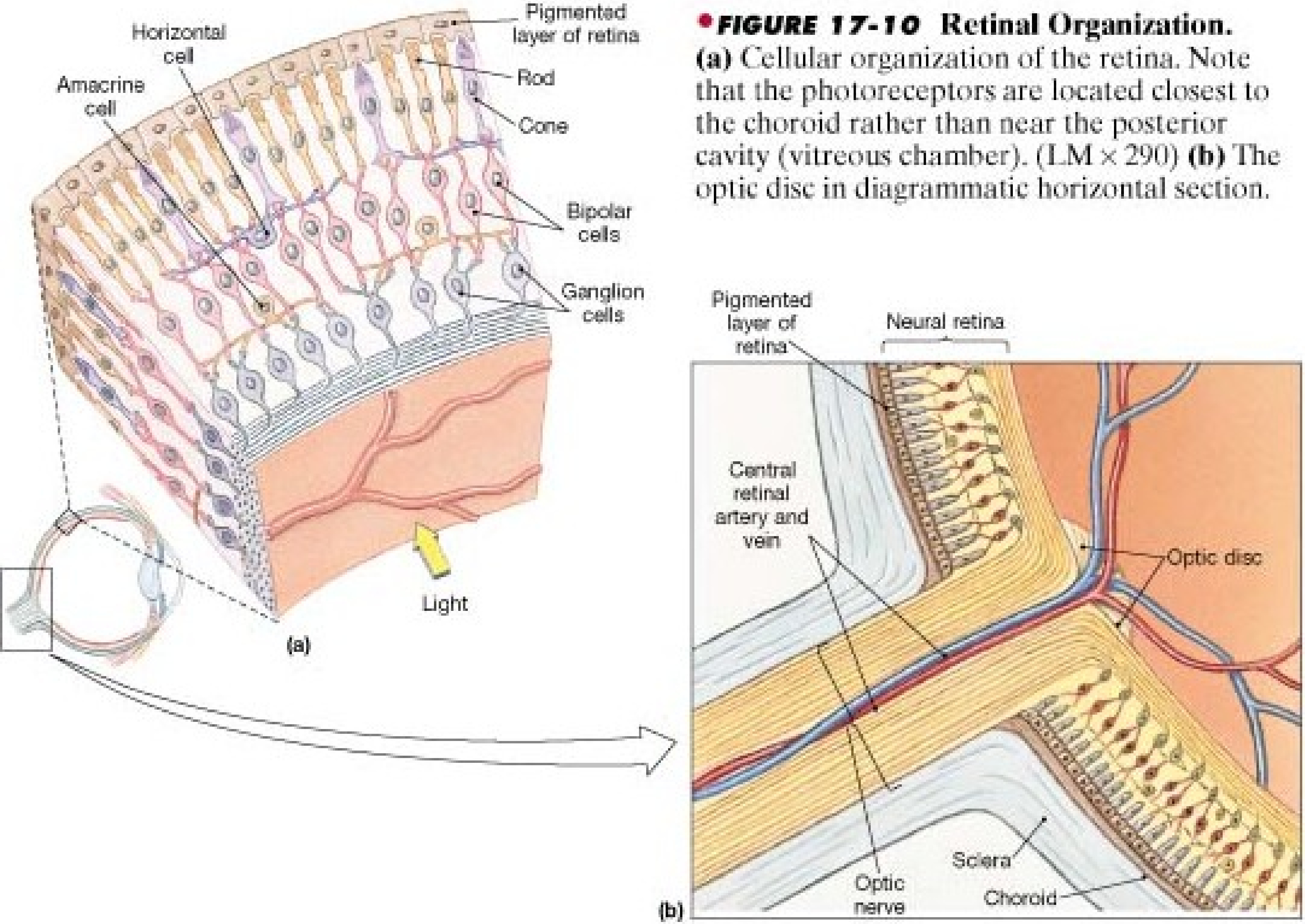
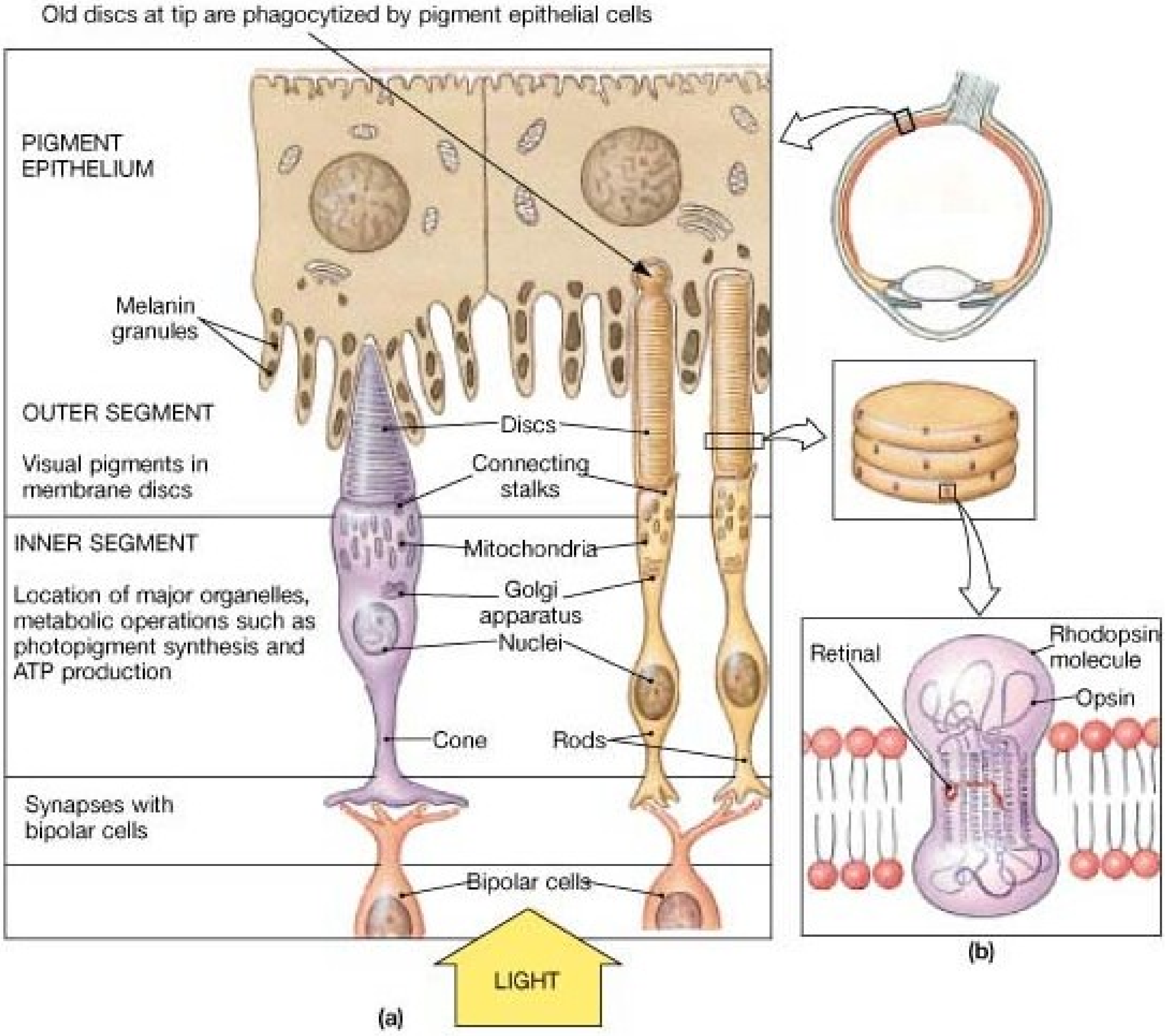
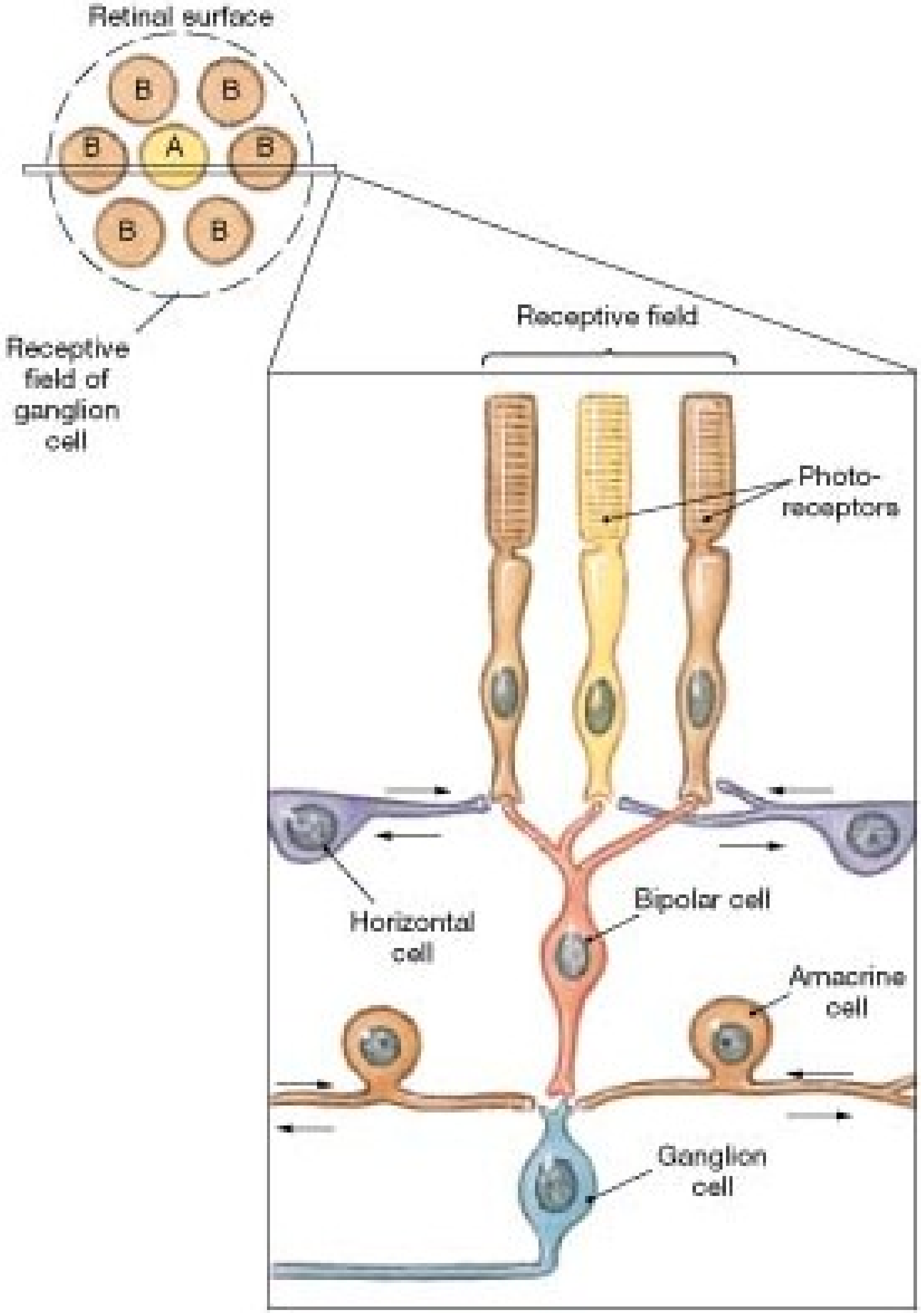


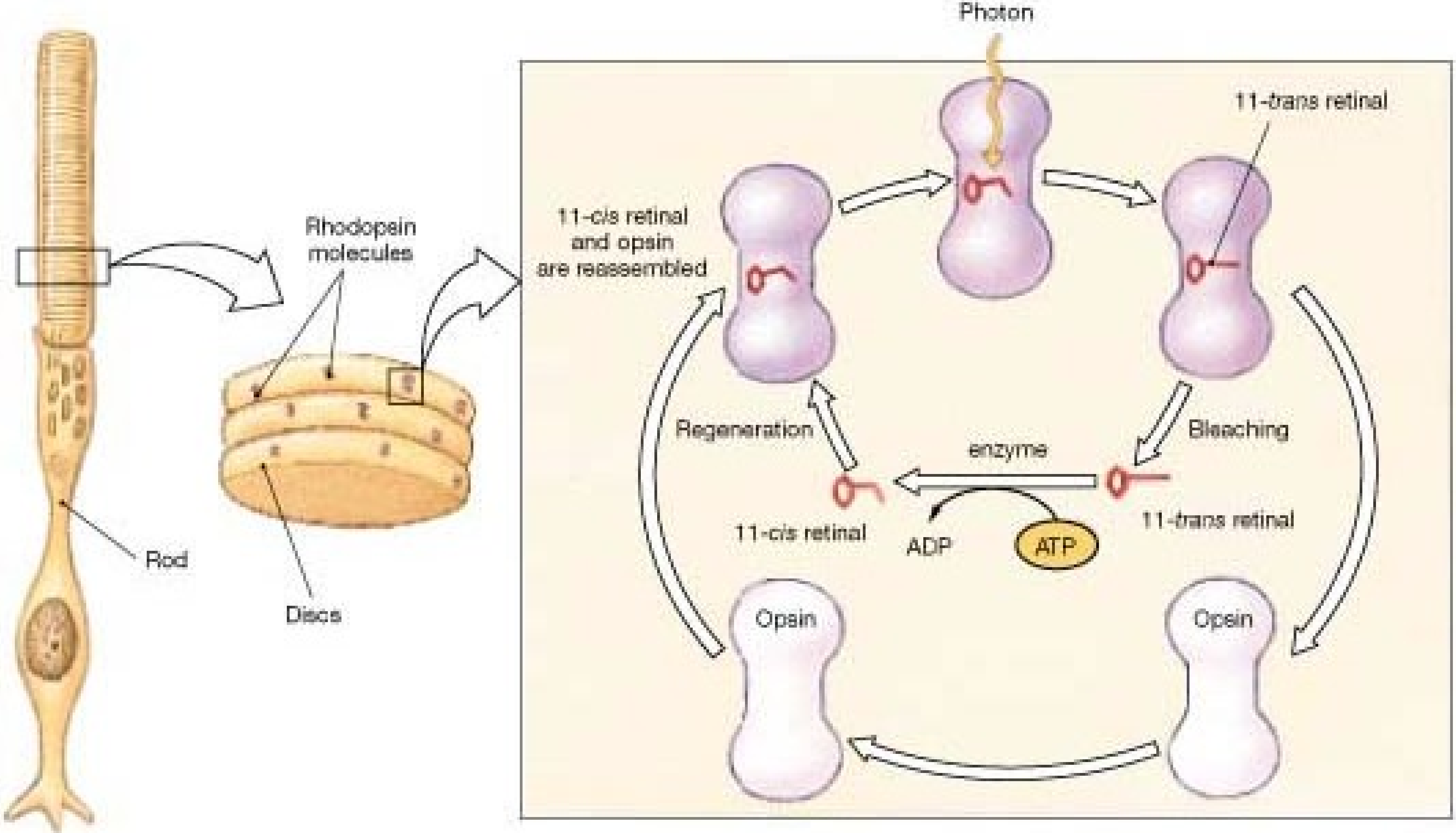
FIGURE 17-10 Retinal Organization. **(a)** Cellular organization of the retina. Note that the photoreceptors are located closest to the choroid rather than near the posterior cavity (vitreous chamber). (LM × 290) **(b)** The optic disc in diagrammatic horizontal section.



Old discs at tip are phagocytized by pigment epithelial cells
PIGMENT EPITHELIUM
Melanin granules
OUTER SEGMENT
Visual pigments in membrane discs
INNER SEGMENT
Location of major organelles, metabolic operations such as photopigment synthesis and ATP production
Synapses with bipolar cells
Discs
Connecting stalks
Mitochondria
Golgi apparatus
Nuclei
Cone
Rods
Bipolar cells
LIGHT
(a)
Retinal
Rhodopsin molecule
Opsin
(b)



• *FIGURE 17-21* Convergence and Ganglion Cell Function. Photoreceptors are organized in groups within the visual field. Each ganglion cell monitors a well-defined portion of the visual field. Some ganglion cells (on-center neurons) respond strongly to light arriving at the center of their receptive field (Receptor A). Others (off-center neurons) respond most strongly to illumination of the edges of their receptive field (Receptors B).



• ***FIGURE 17-19*** **Bleaching and Regeneration of Visual Pigments**

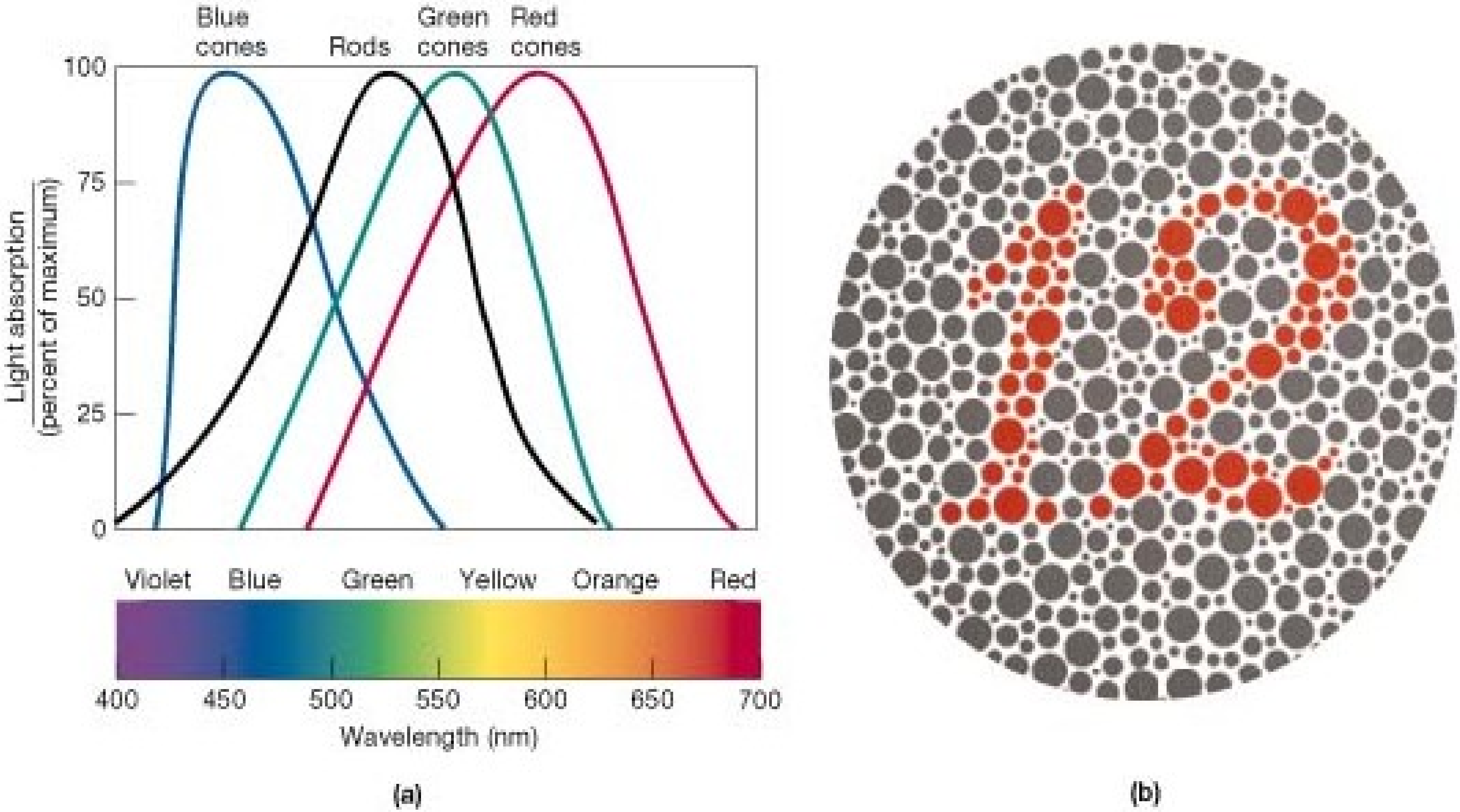


FIGURE 17-20 Cones and Color Vision. **(a)** A graph comparing the absorptive characteristics of blue, green, and red cones with those of typical rods. Notice that the rod sensitivities overlap those of the cones and that the various cone types have overlapping sensitivity curves. **(b)** Part of a standard test for color vision. If you lack one or more populations of cones, you will be unable to distinguish the patterned image (the number 12).

Retina

- **Optic disk** - (blind spot) the point where nerve fibers from retina leave the eye and become the optic nerve.
- Function - it is a blind spot that represents the beginning of the optic nerve.

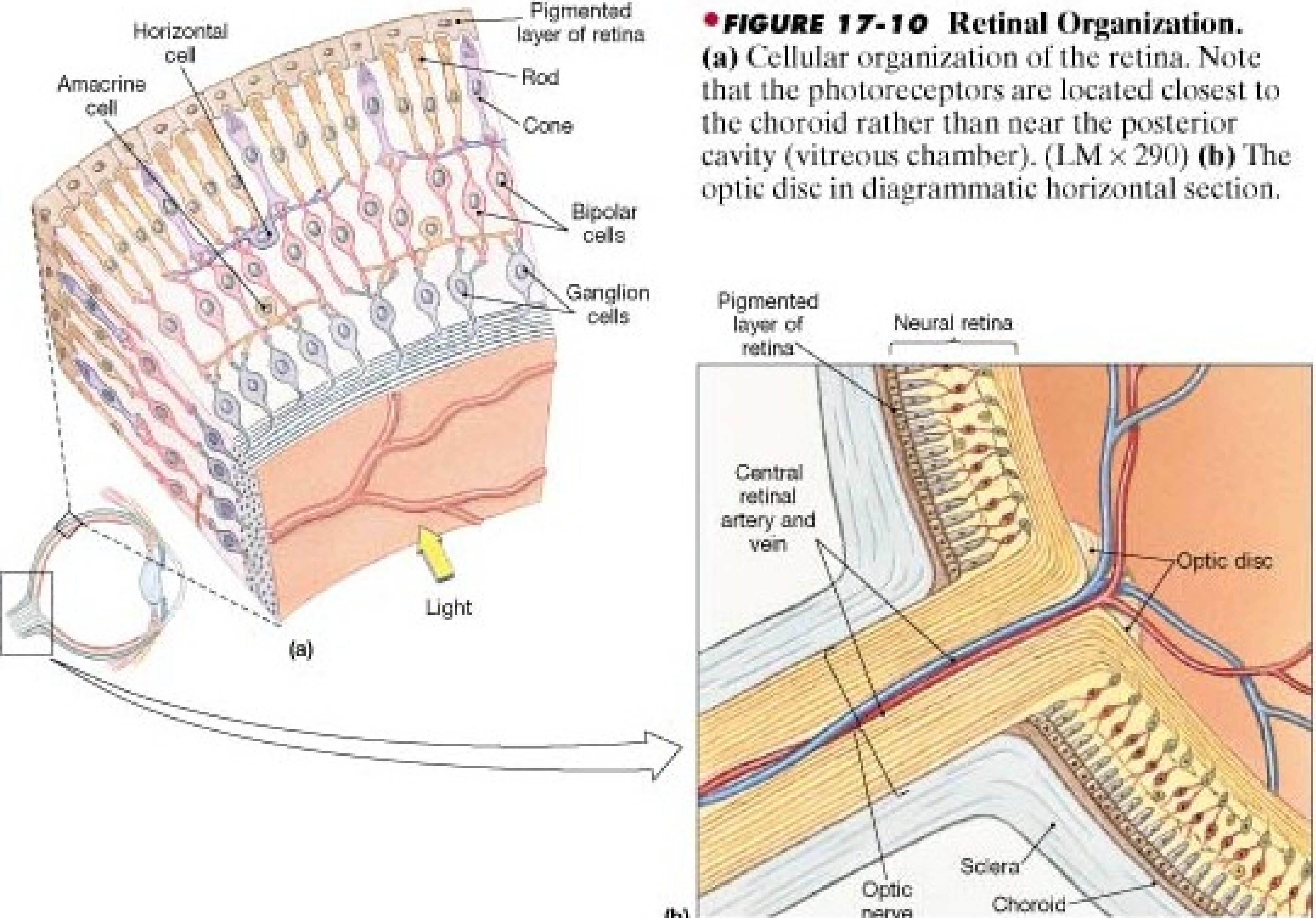


FIGURE 17-10 Retinal Organization. **(a)** Cellular organization of the retina. Note that the photoreceptors are located closest to the choroid rather than near the posterior cavity (vitreous chamber). (LM × 290) **(b)** The optic disc in diagrammatic horizontal section.

Lens

- The Lens is a flexible, transparent structure consisting of the proteins called crystallins, arranged like the layers of an onion & enclosed by a clear connective tissue capsule.
- It lies directly behind the Iris

Lens

- It is held in place by the suspensory ligaments which encircle it.
- Function - **focus** image on the retina
- Cataracts - are the leading cause of blindness due a loss of transparency of the lens. Often occurs with aging or by exposure to ultraviolet rays, medications (steroids), diabetes, smoking, etc.
- Sight can be restored removal of lens and & implantation of an artificial one.

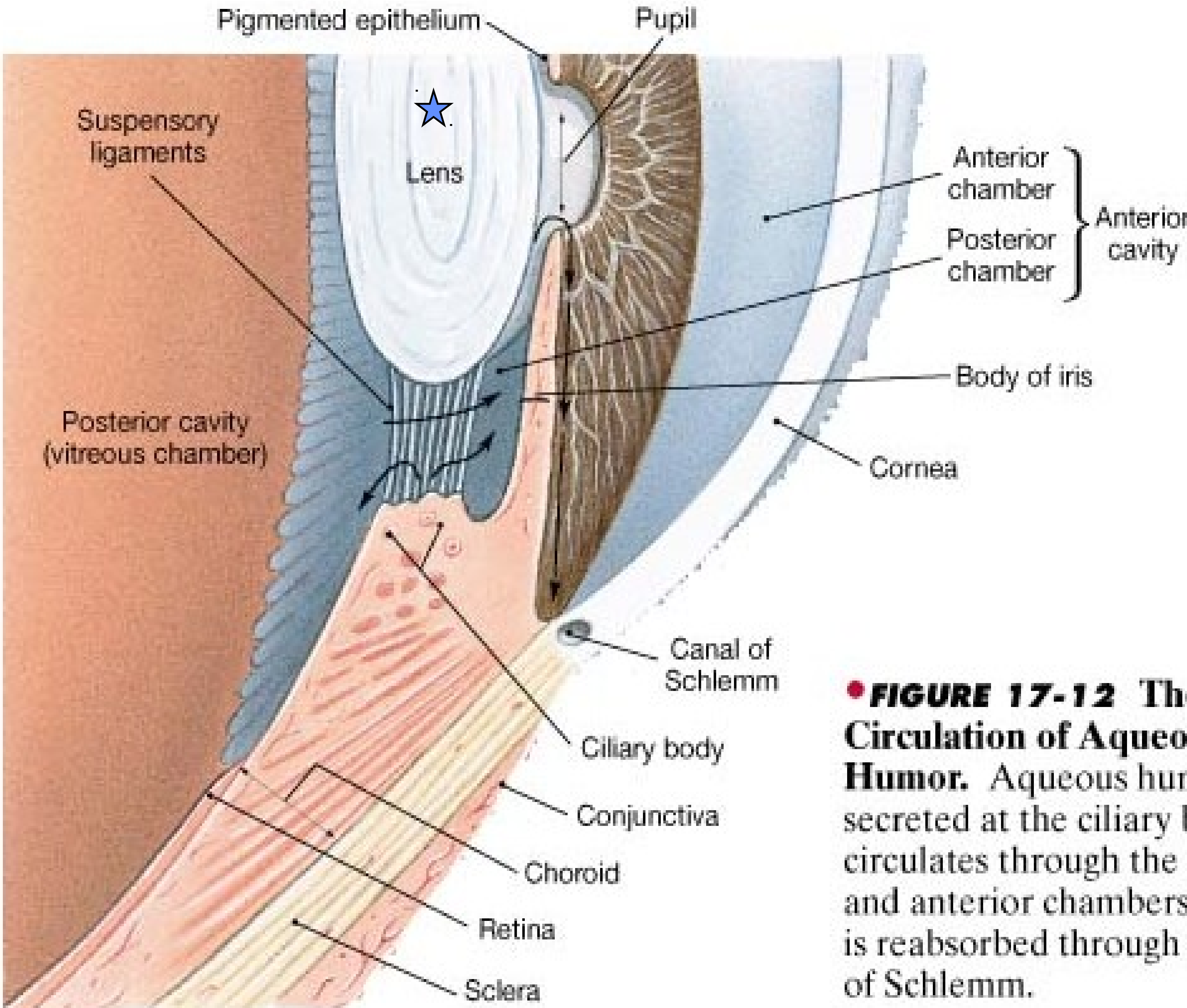


FIGURE 17-12 The Circulation of Aqueous Humor. Aqueous humor secreted at the ciliary body circulates through the posterior and anterior chambers before it is reabsorbed through the canal of Schlemm.

Vitreous humor

- A clear, jelly-like fluid located in posterior cavity of eye behind the Lens.
- Function - to support the internal parts of the eye and helps maintain its shape.

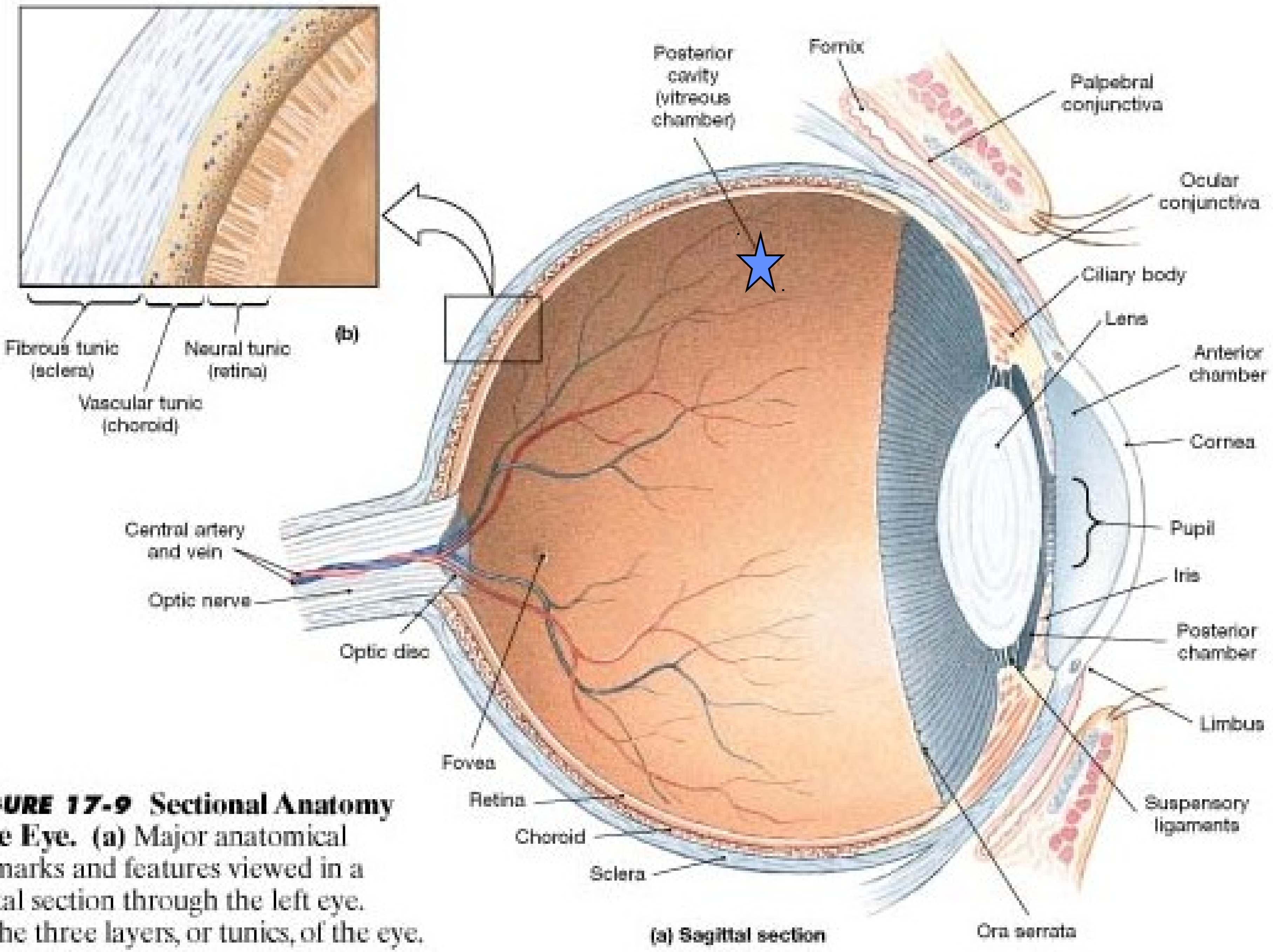


FIGURE 17-9 Sectional Anatomy of the Eye. **(a)** Major anatomical landmarks and features viewed in a sagittal section through the left eye. **(b)** The three layers, or tunics, of the eye.

Sight & Image Formation

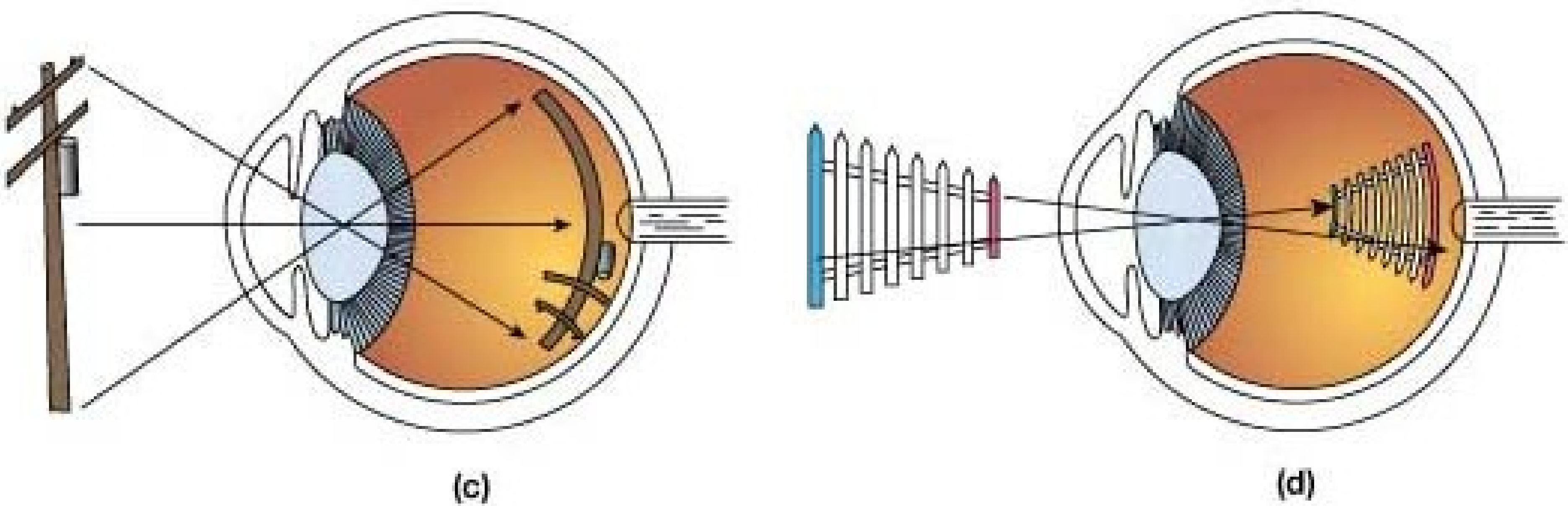
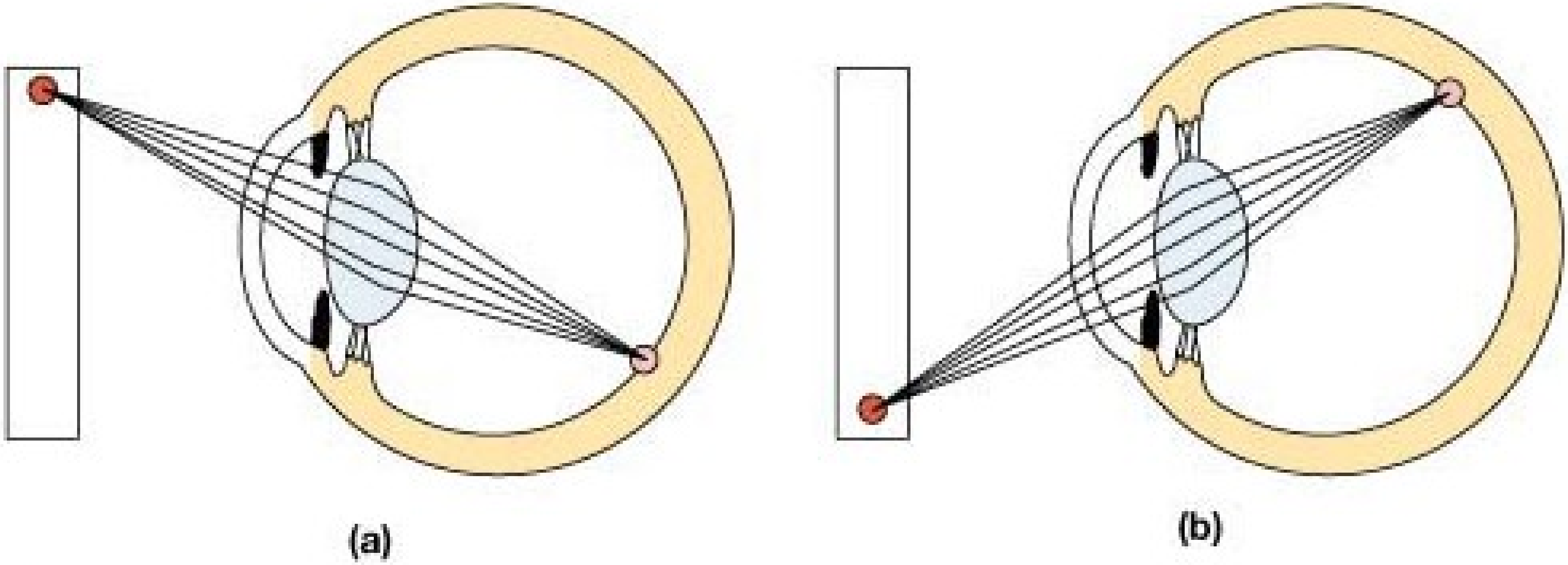
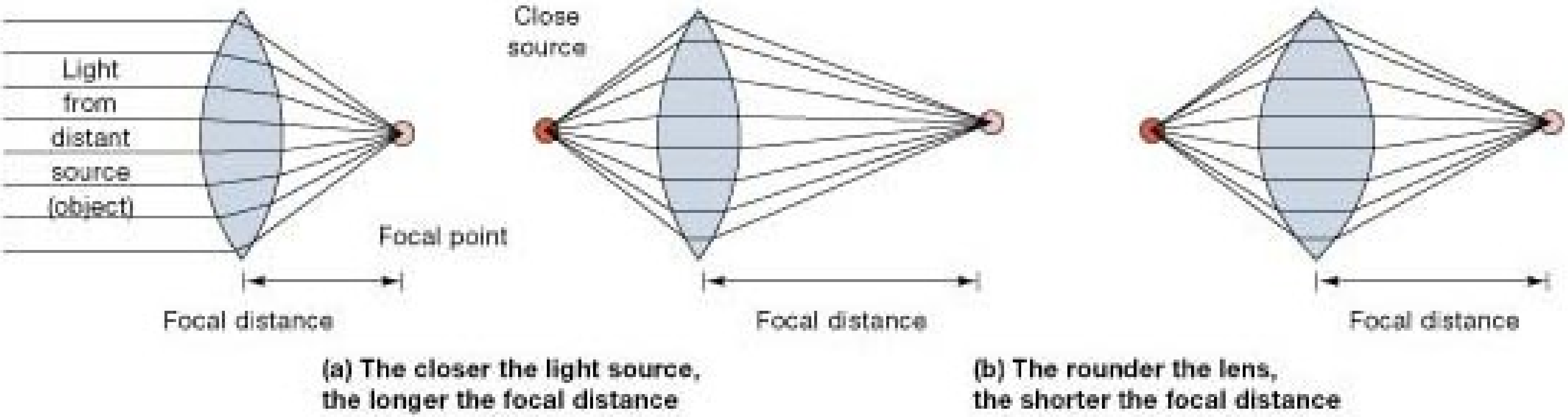


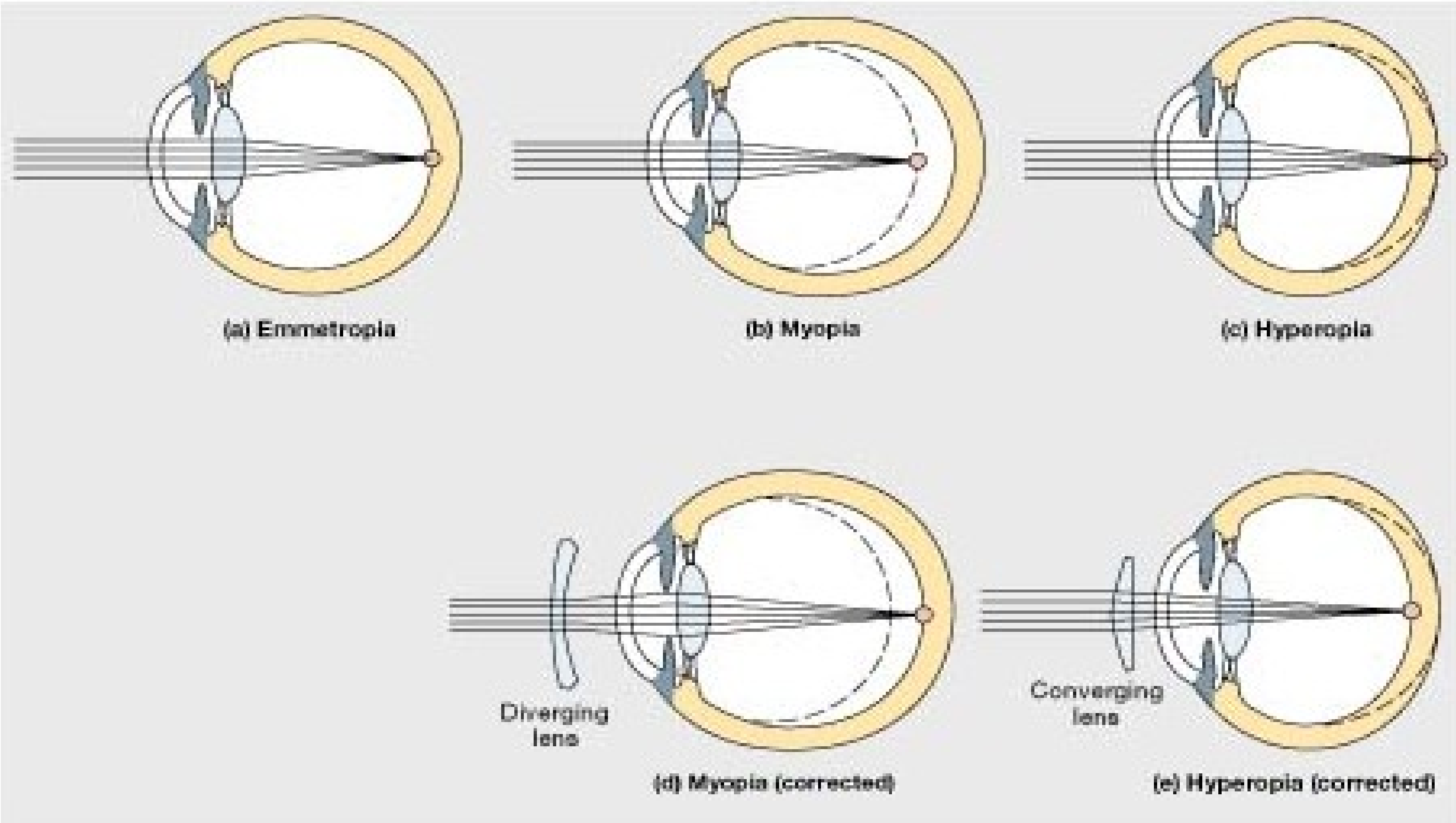
FIGURE 17-16 Image Formation. The resulting image arrives **(c, d)** upside down and backward.



• ***FIGURE 17-16*** **Image Formation. (a,b)** Light from each portion of an object is focused on a different part of the retina.

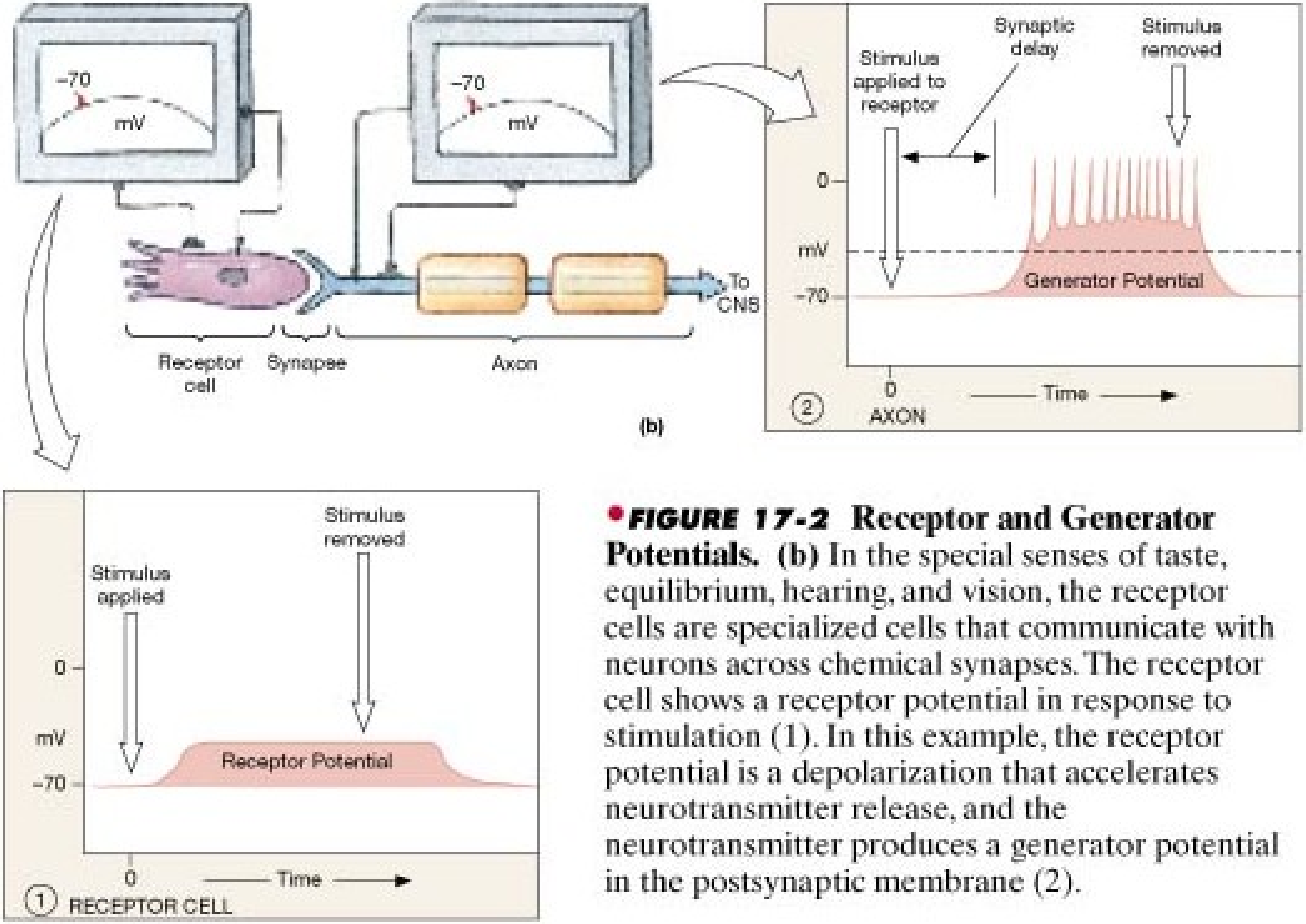


• ***FIGURE 17-13*** **Principles of Image Formation.** Light rays from a given source are refracted when they reach the lens of the eye. From the lens, the rays are focused onto a single focal point. **(a)** The focal distance increases as the object nears the lens. **(b)** A rounder lens has a shorter focal distance than a flatter lens does.

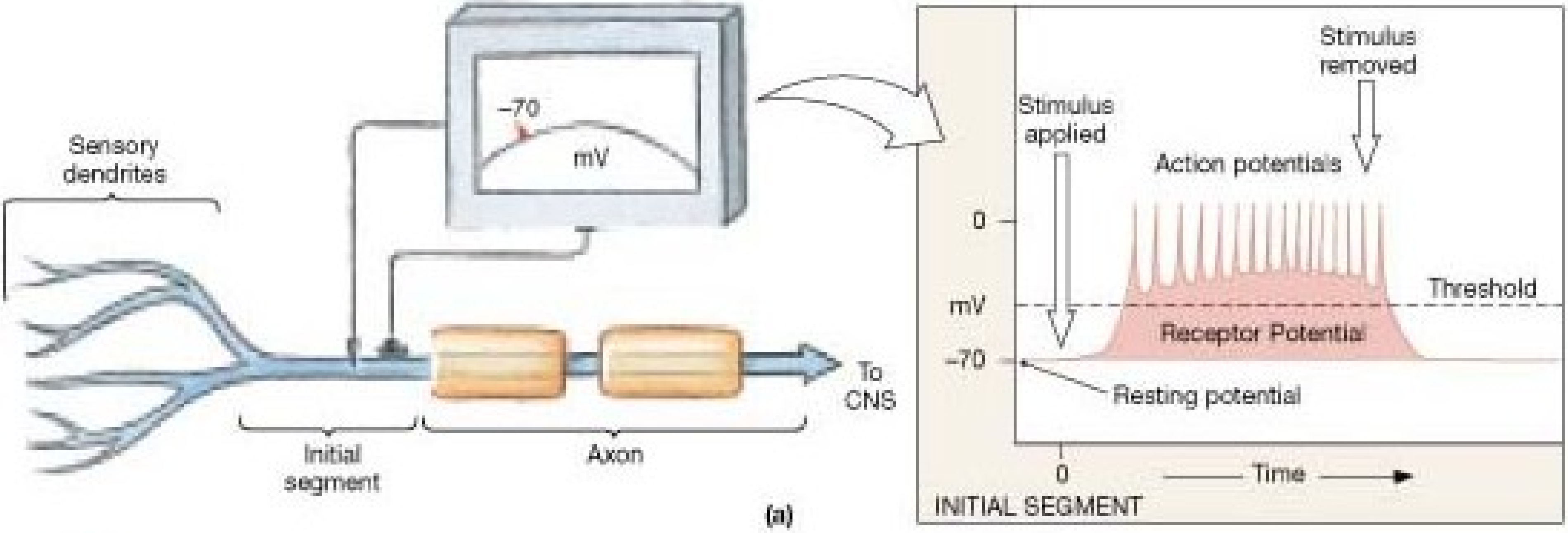


• ***FIGURE 17-15*** **Visual Abnormalities.** **(a)** In normal vision, the lens focuses the visual image on the retina. Common problems with the accommodation mechanism involve **(b)** myopia, an inability to lengthen the focal distance enough to focus the image of a distant object on the retina, and **(c)** hyperopia, an inability to shorten the focal distance adequately for nearby objects. These conditions can be corrected by placing appropriately shaped lenses in front of the eyes. **(d)** A diverging lens is used to correct myopia, and **(e)** a converging lens is used to correct hyperopia.

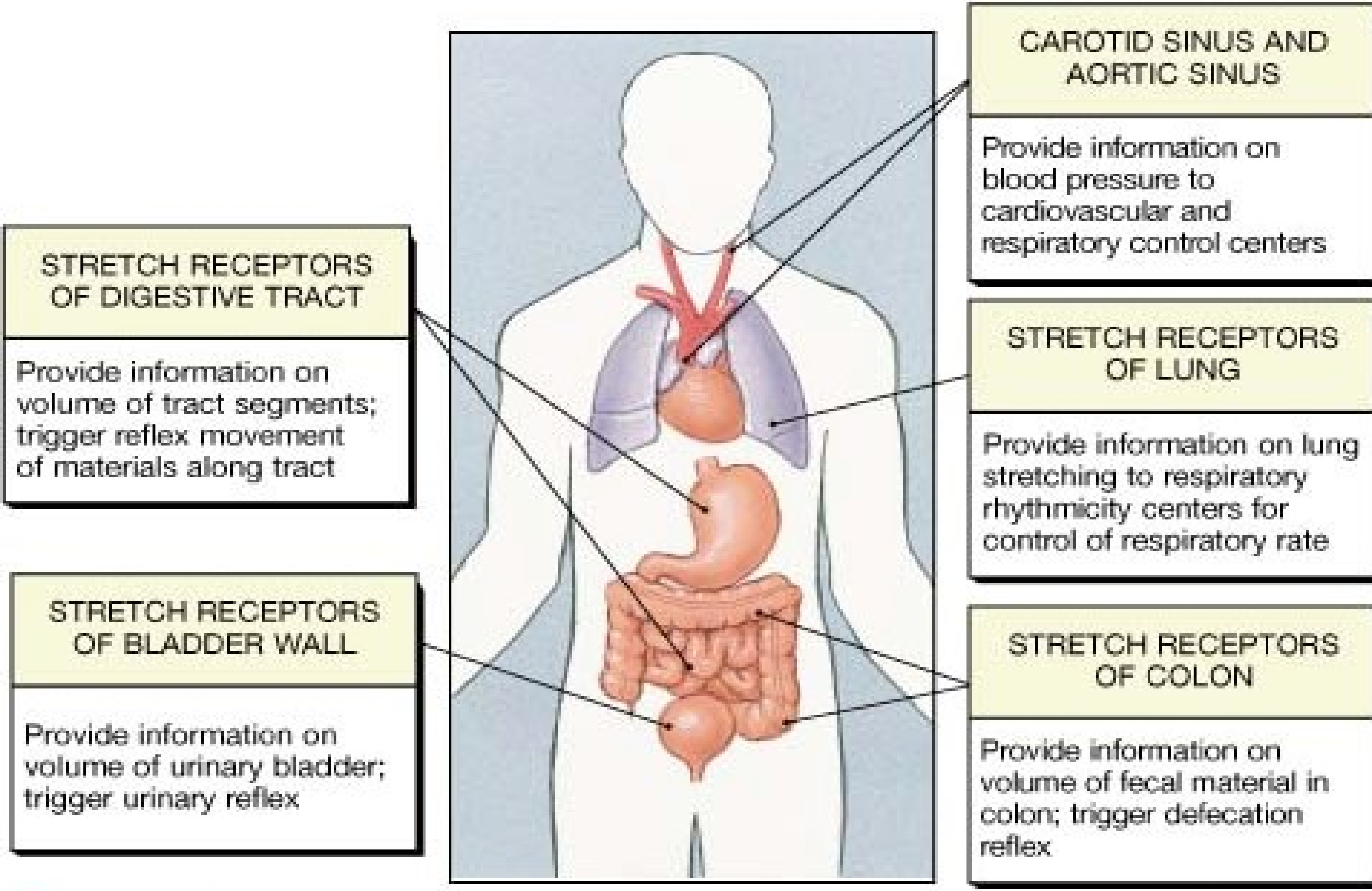
Sensory Receptors



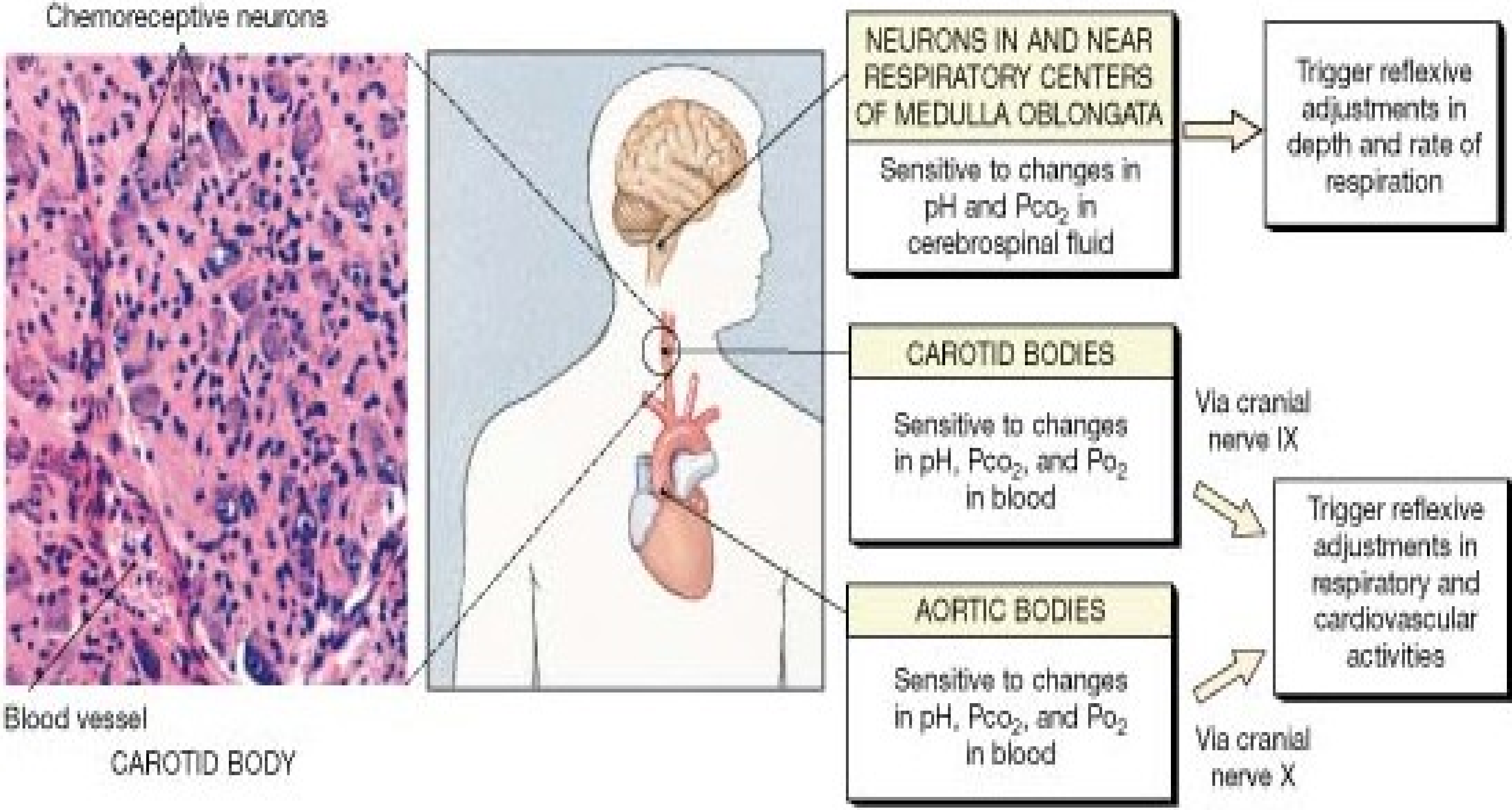
• ***FIGURE 17-2*** **Receptor and Generator Potentials.** **(b)** In the special senses of taste, equilibrium, hearing, and vision, the receptor cells are specialized cells that communicate with neurons across chemical synapses. The receptor cell shows a receptor potential in response to stimulation (1). In this example, the receptor potential is a depolarization that accelerates neurotransmitter release, and the neurotransmitter produces a generator potential in the postsynaptic membrane (2).



• ***FIGURE 17-2*** **Receptor and Generator Potentials. (a)** When the sensory neuron acts as the receptor, a stimulus that depolarizes the dendrites may bring the initial segment of the axon to threshold. The receptor and the neuron are the same cell, so the receptor potential is a generator potential.



• ***FIGURE 17-4*** **Baroreceptors and the Regulation of Autonomic Functions.** Baroreceptors provide information essential to the regulation of autonomic activities, including cardiovascular function, urination, defecation, and respiration.



•***FIGURE 17-5*** **Chemoreceptors.** Chemoreceptors are located inside the CNS, on the ventrolateral surfaces of the medulla oblongata, and in the aortic and carotid bodies. These receptors are involved in the autonomic regulation of cardiovascular and respiratory function. The micrograph shows the histological appearance of the chemoreceptive neurons in the carotid body. (LM × 1150)

Sensory Receptors of The Skin

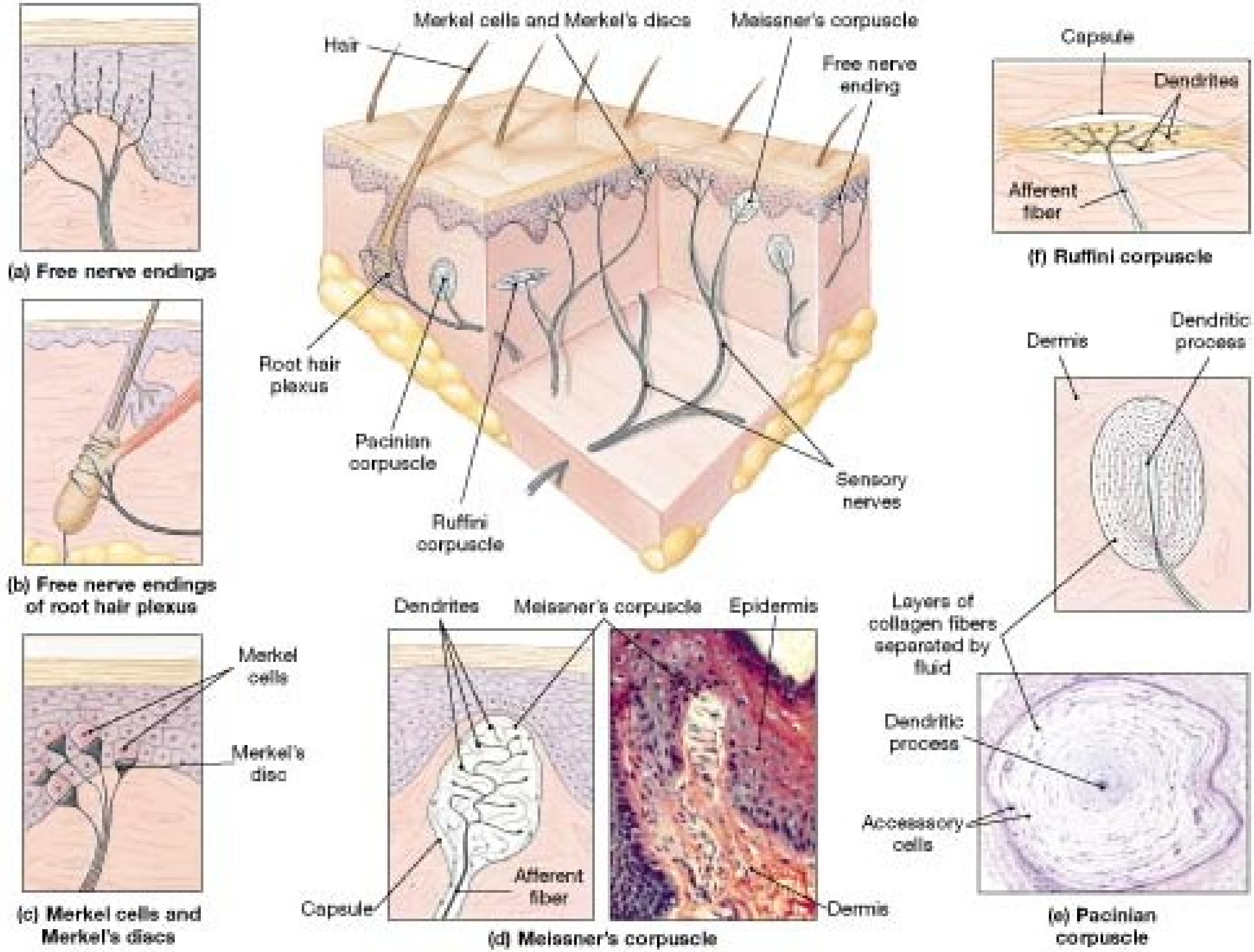


FIGURE 17-3 Tactile Receptors in the Skin. **(a)** Free nerve endings. **(b)** Root hair plexus. **(c)** Merkel cells and Merkel's discs. **(d)** Meissner's corpuscle. **(e)** Pacinian corpuscle. **(f)** Ruffini corpuscle.

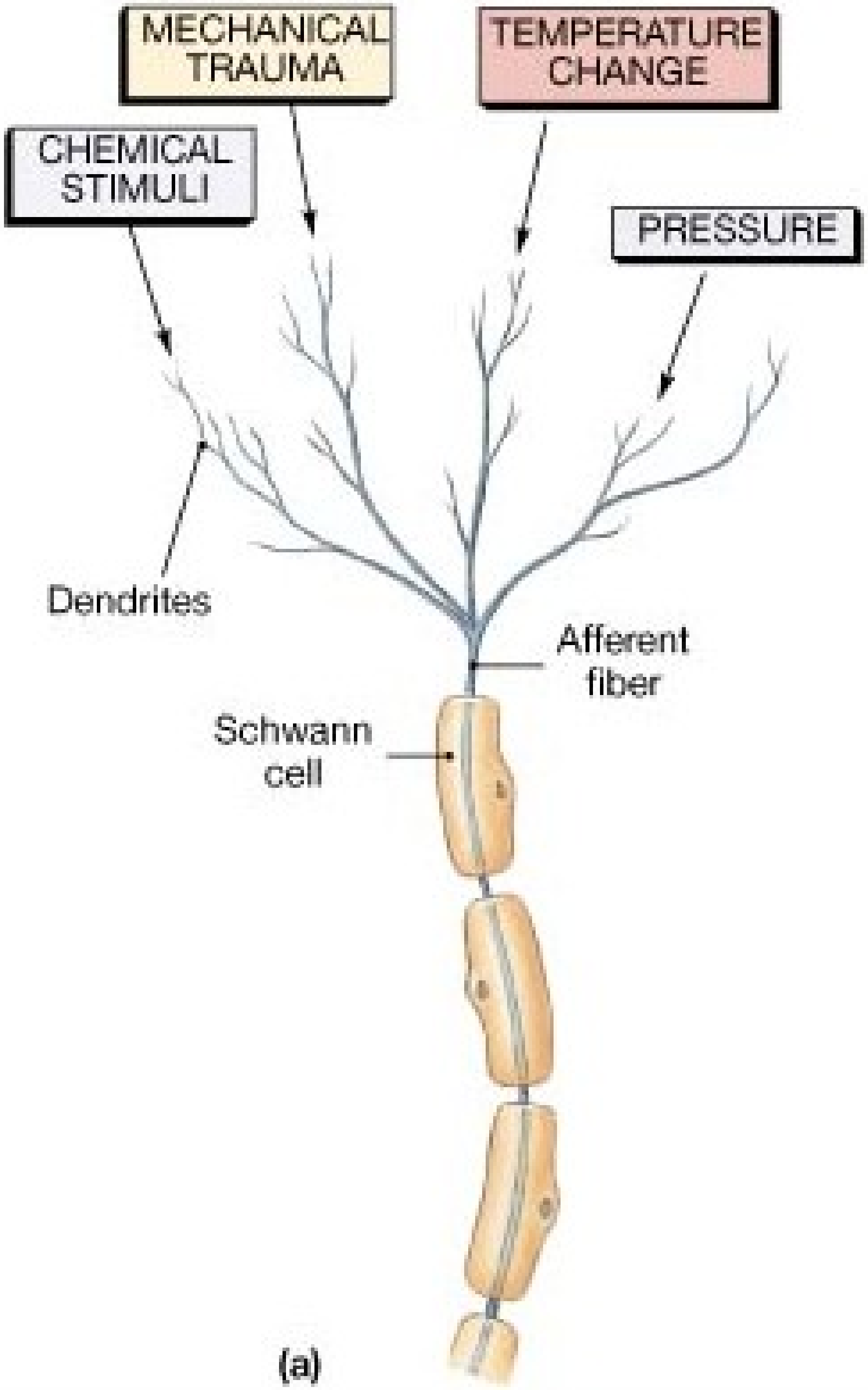
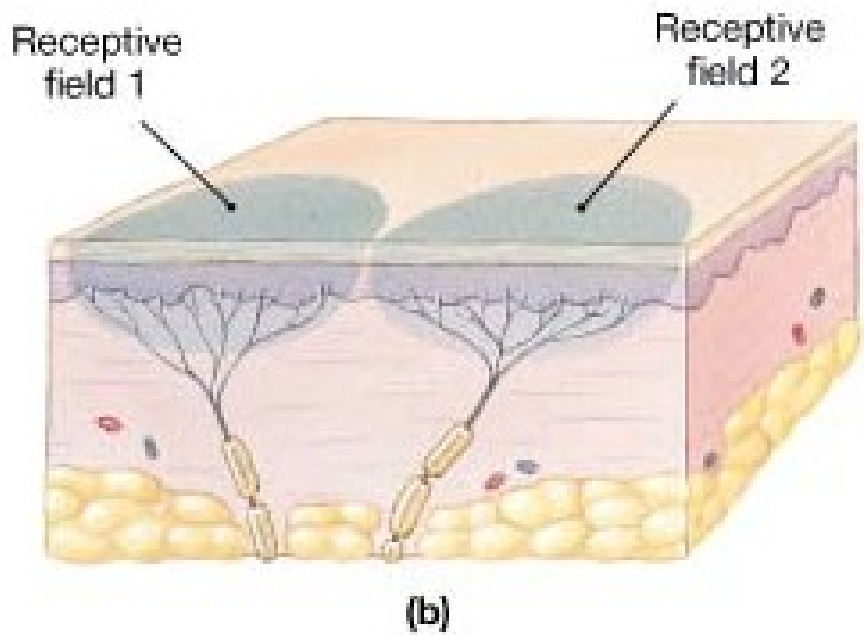


FIGURE 17-1 Receptors and Receptive Fields. **(a)** A free nerve ending consists of sensory dendrites that may be stimulated by a variety of stimuli. **(b)** Each receptor monitors a specific area known as the receptive field.



Sense of Taste

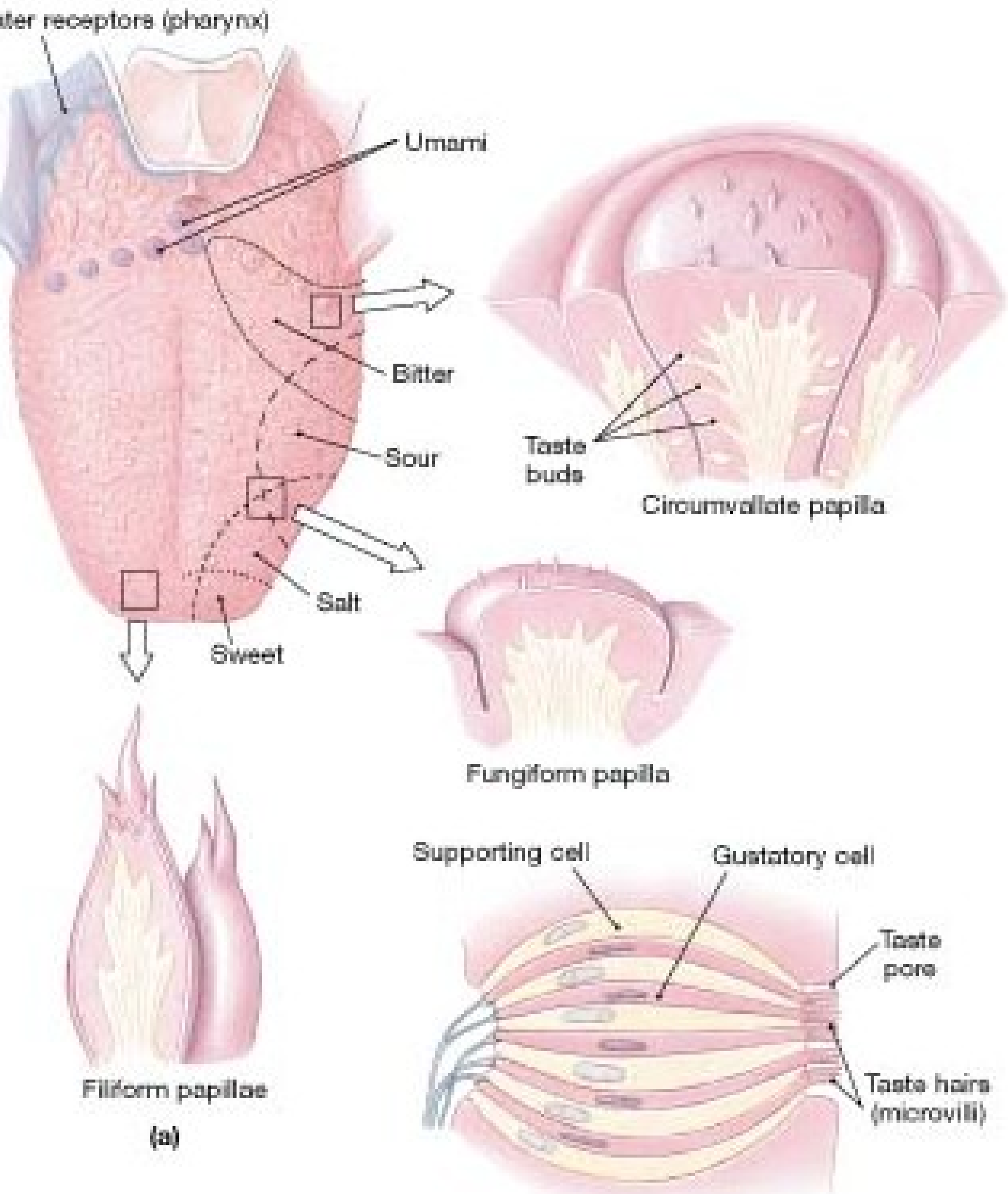
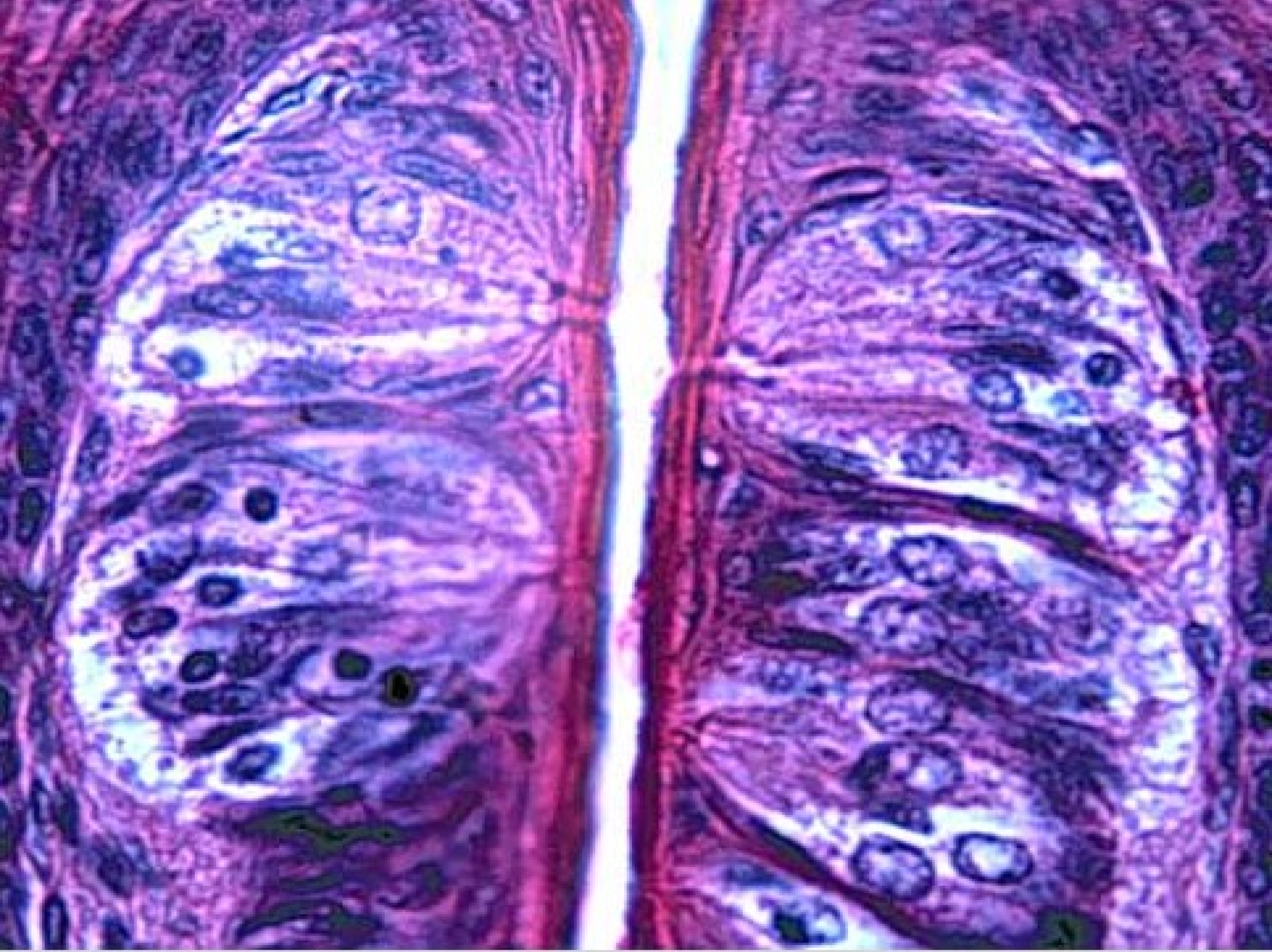
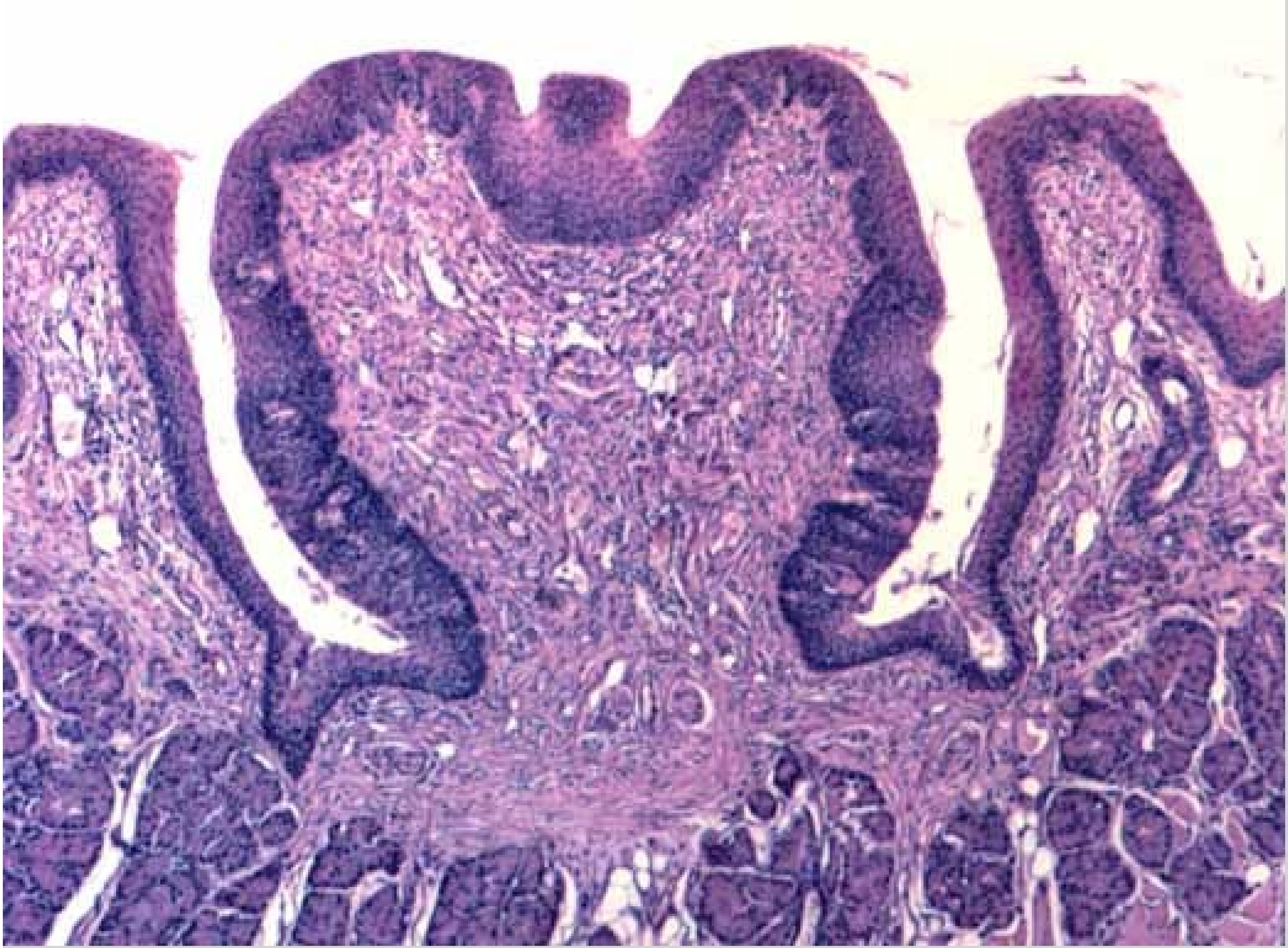


FIGURE 17-7 Gustatory Reception. **(a)** Gustatory receptors are located in taste buds that form pockets in the epithelium of the fungiform and circumvallate papillae.





Sense of Smell

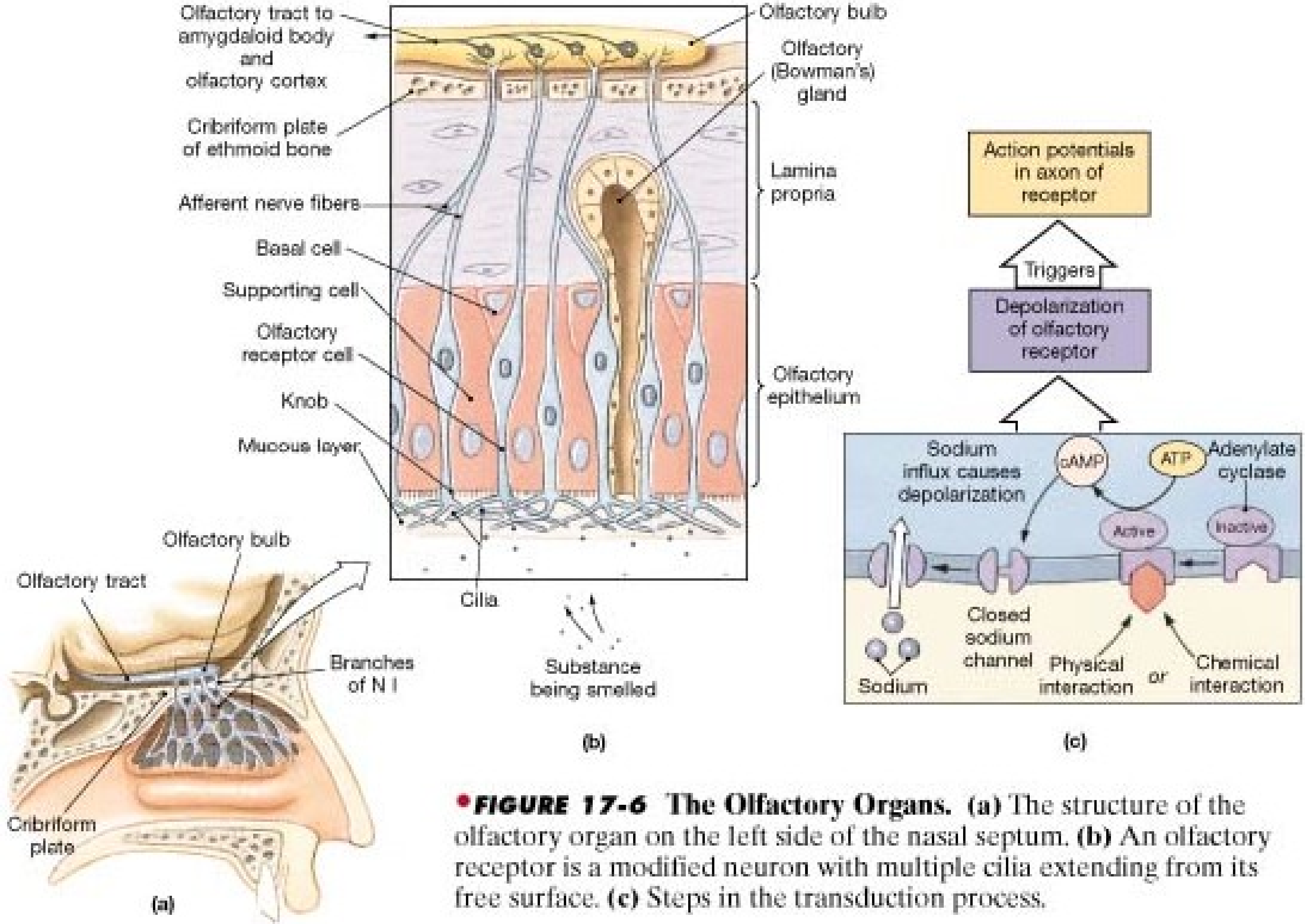
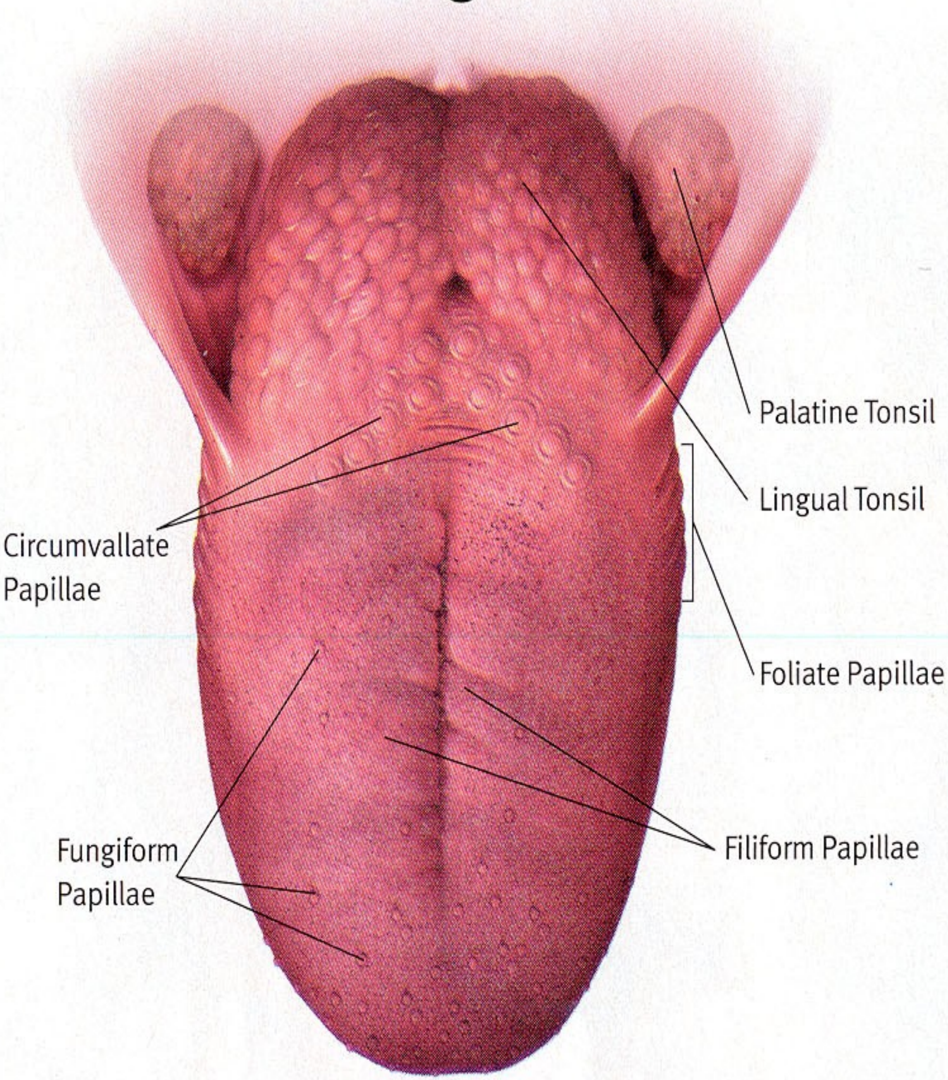
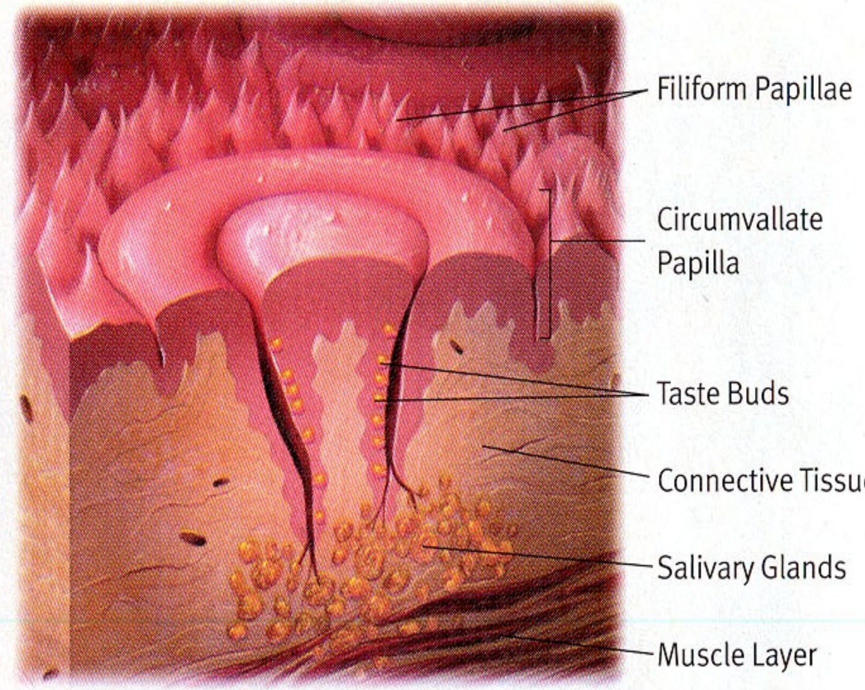


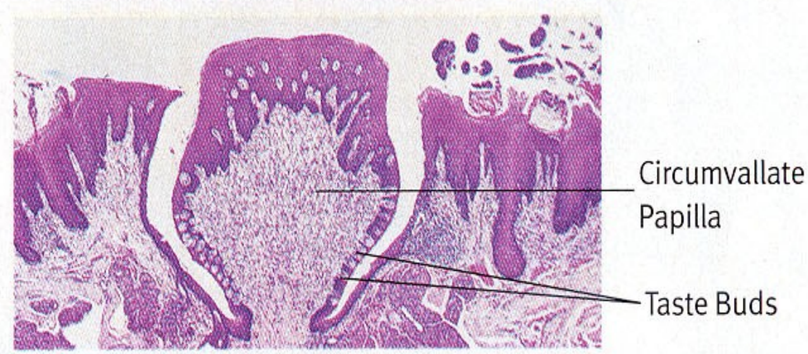
FIGURE 17-6 The Olfactory Organs. **(a)** The structure of the olfactory organ on the left side of the nasal septum. **(b)** An olfactory receptor is a modified neuron with multiple cilia extending from its free surface. **(c)** Steps in the transduction process.

Tongue

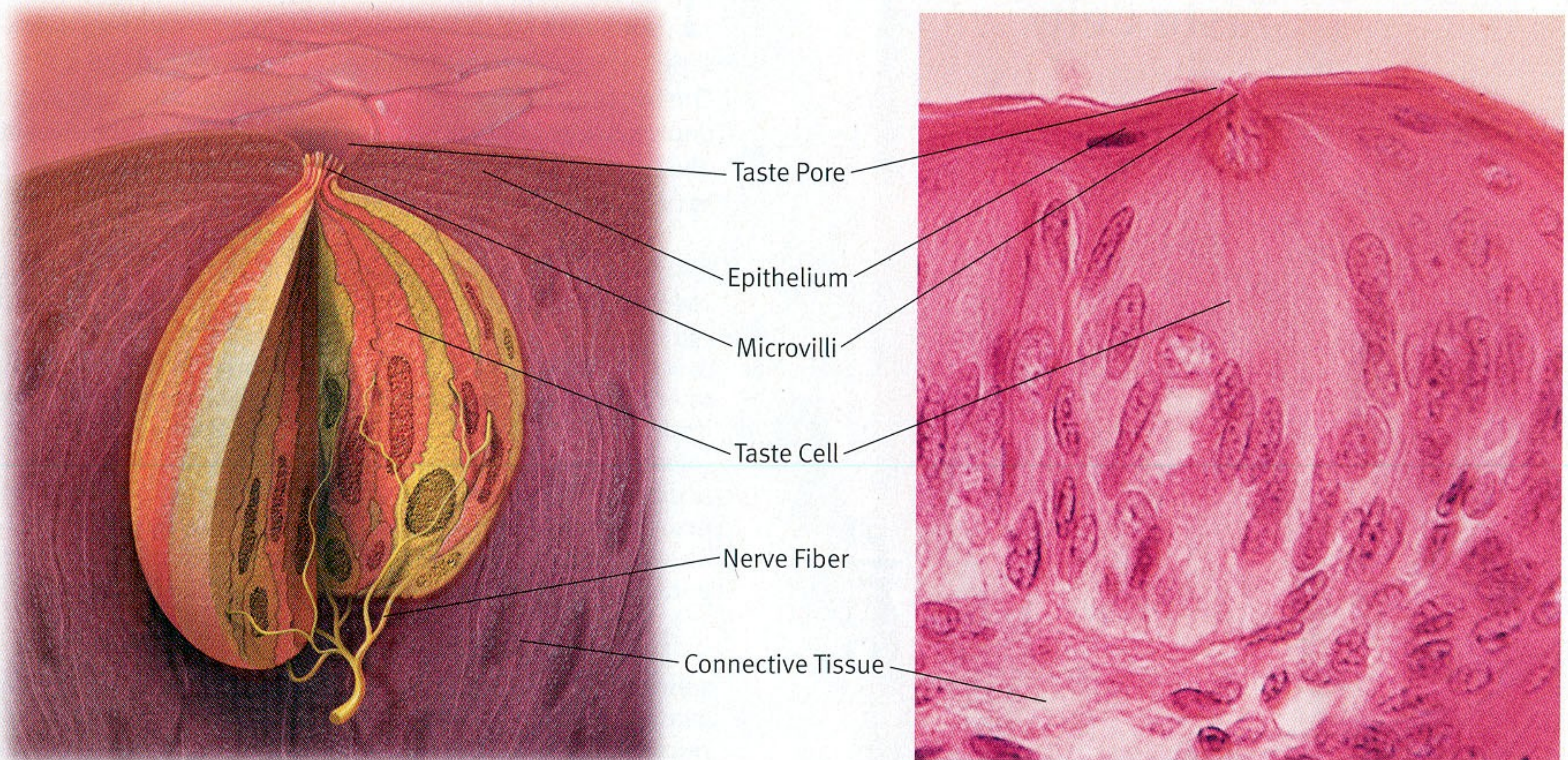


Circumvallate Papilla



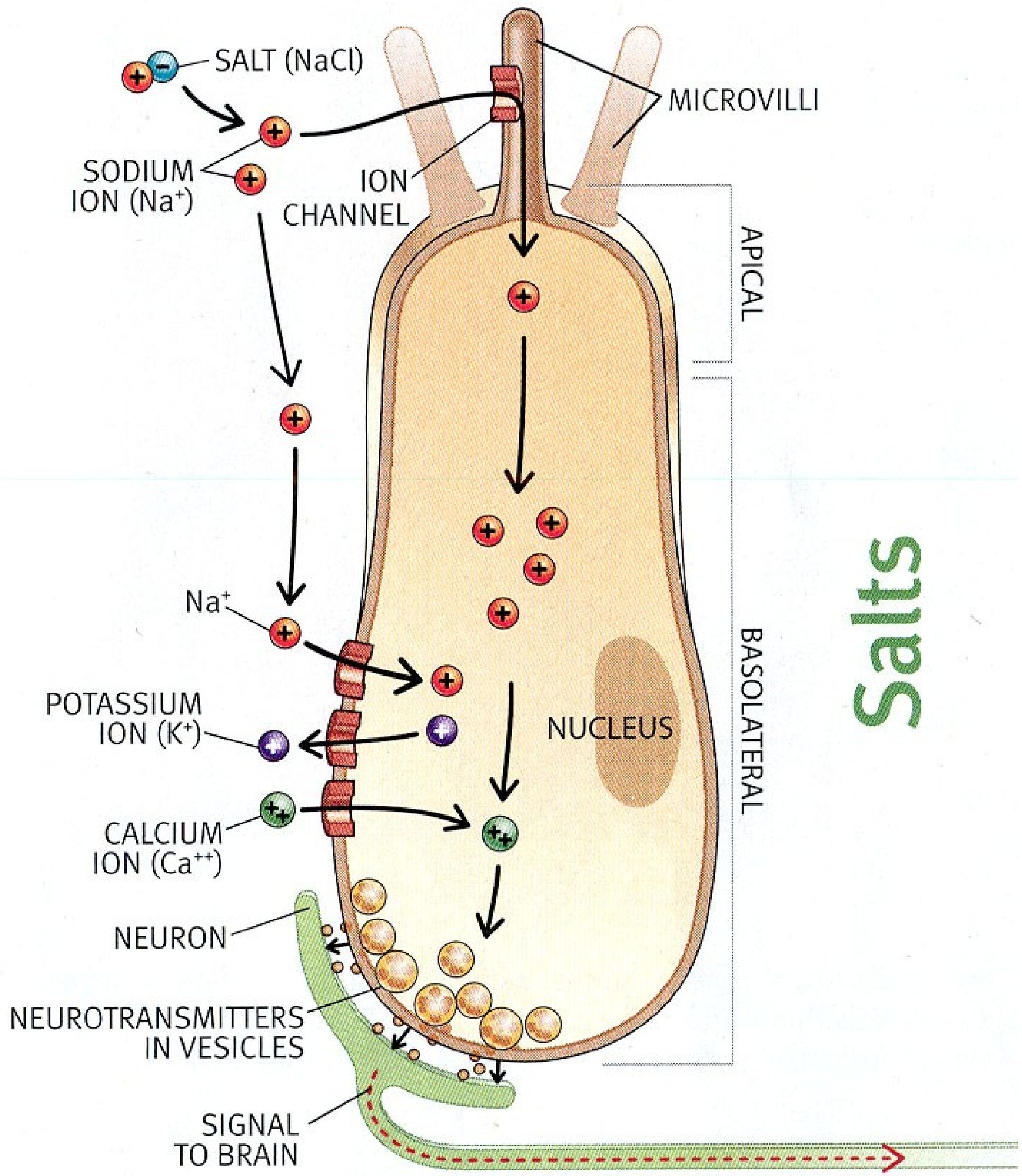


Taste Bud

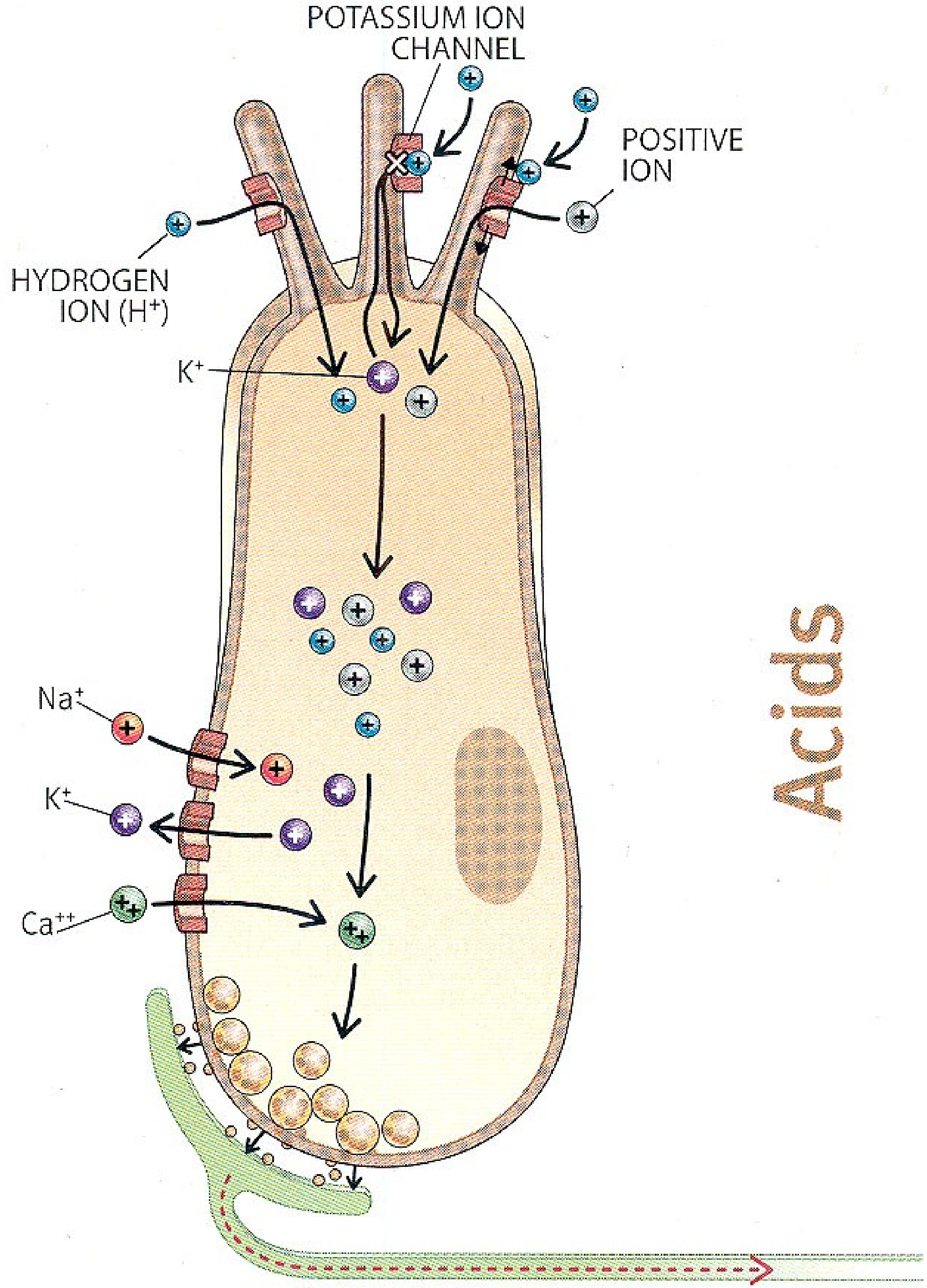


from food called tastants enter the taste pores of taste buds, where they interact with molecules on fingerlike processes called microvilli on the surfaces of specialized taste cells. The interactions trigger electrochemical changes in the taste cells that cause them to transmit signals that ultimately reach the brain. The impulses are interpreted, together with smell and other sensory input, as flavors.

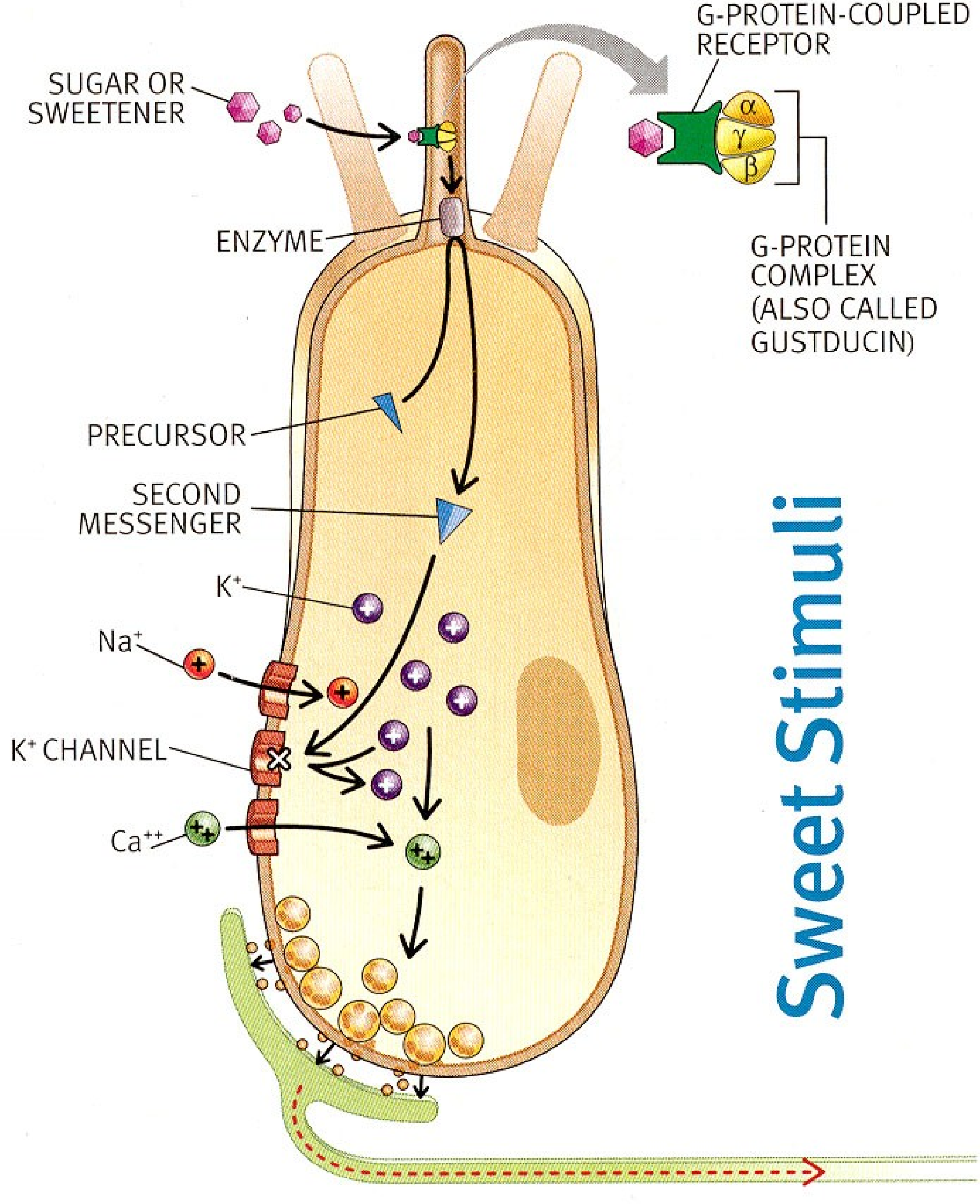
Taste Cell



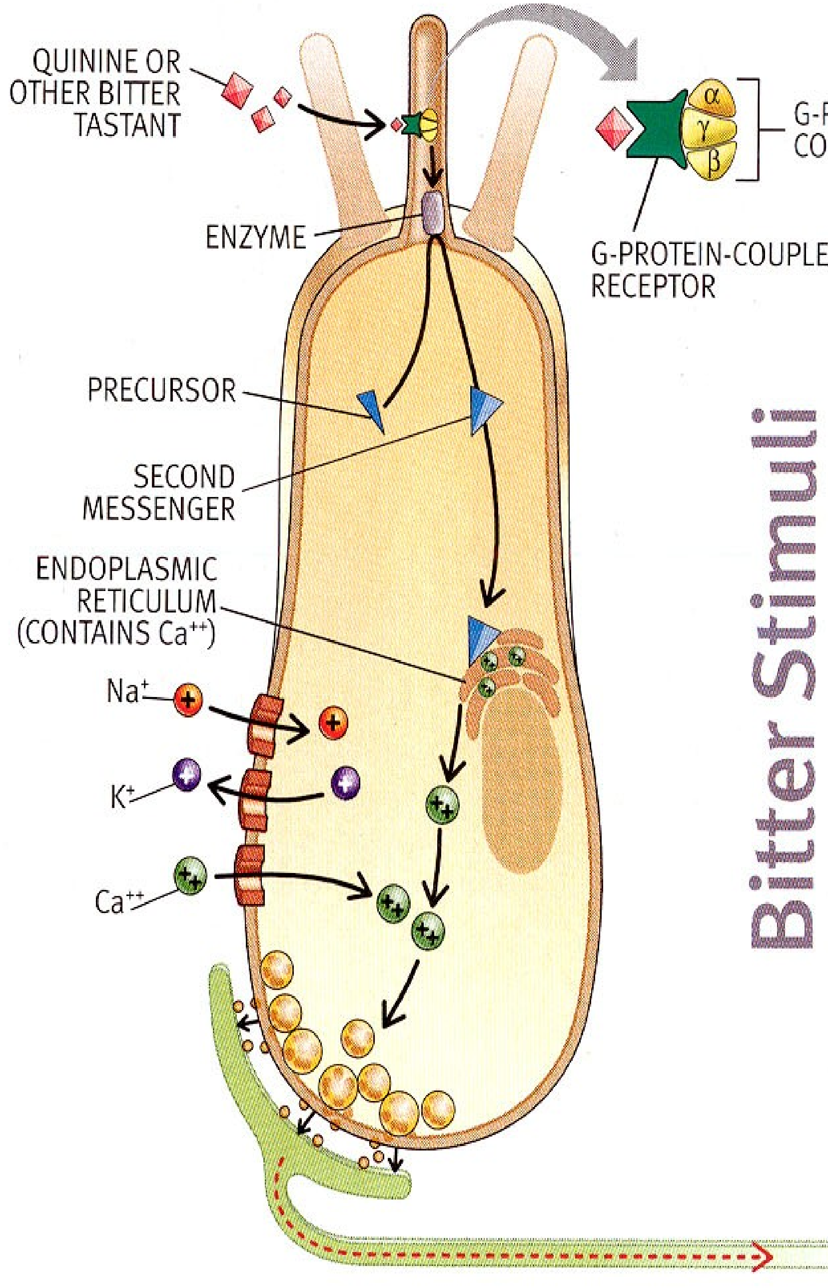
SALT (NaCl)
MICROVILLI
SODIUM ION (Na⁺)
ION CHANNEL
APICAL
BASOLATERAL
Na⁺
POTASSIUM ION (K⁺)
NUCLEUS
CALCIUM ION (Ca⁺⁺)
NEURON
NEUROTRANSMITTERS IN VESICLES
SIGNAL TO BRAIN
Salts

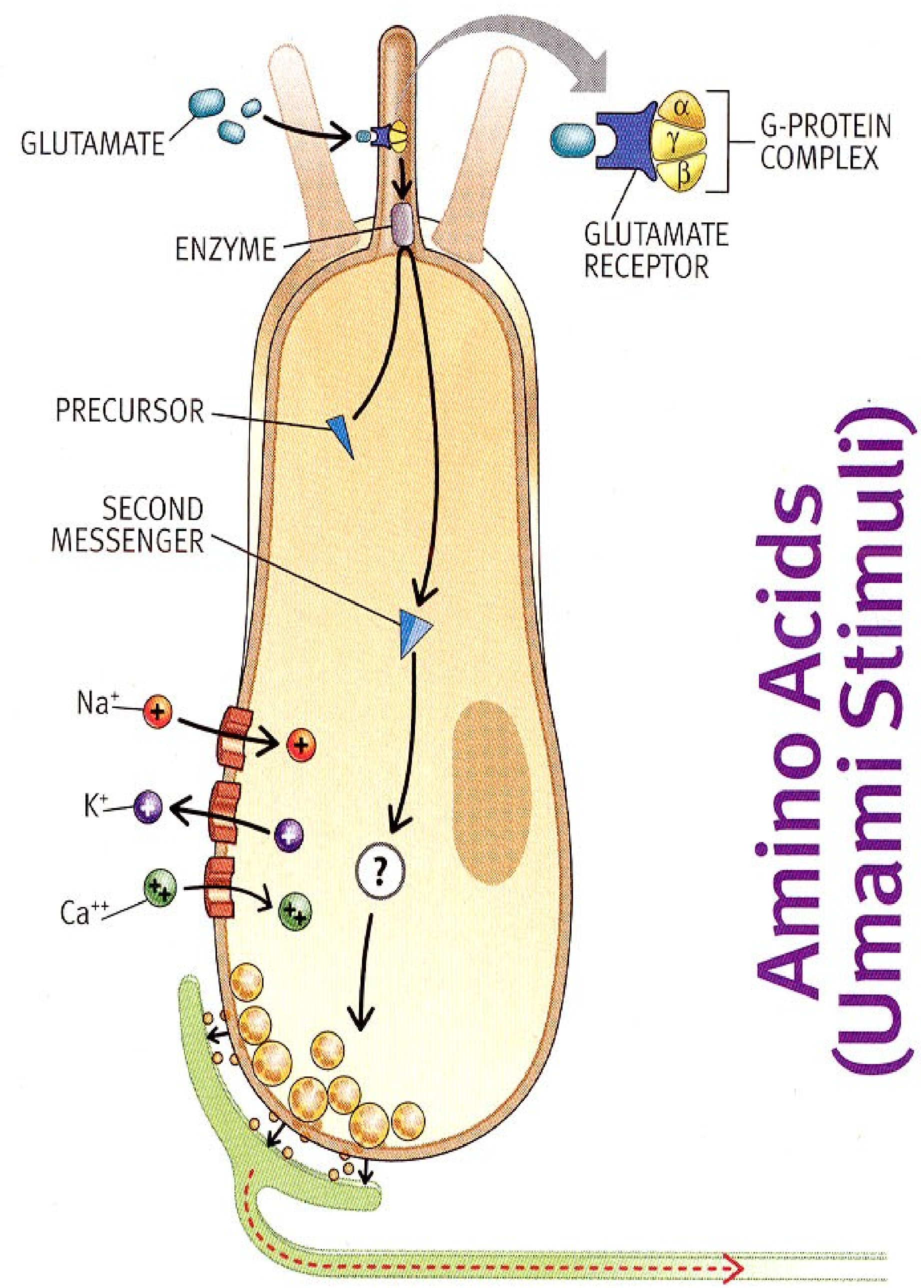


POTASSIUM ION CHANNEL
POSITIVE ION
HYDROGEN ION (H⁺)
K⁺
Na⁺
K⁺
Ca⁺⁺



Sweet Stimuli


QUININE OR
OTHER BITTER
TASTANT
G-PROTEIN
COMPLEX
α
γ
β
ENZYME
G-PROTEIN-COUPLED
RECEPTOR
PRECURSOR
SECOND
MESSENGER
ENDOPLASMIC
RETICULUM
(CONTAINS Ca++)
Na+
K+
Ca++
Bitter Stimuli


GLUTAMATE
G-PROTEIN
COMPLEX
α
γ
β
ENZYME
GLUTAMATE
RECEPTOR
PRECURSOR
SECOND
MESSENGER
Na+
K+
Ca++
?
Amino Acids
(Umami Stimuli)

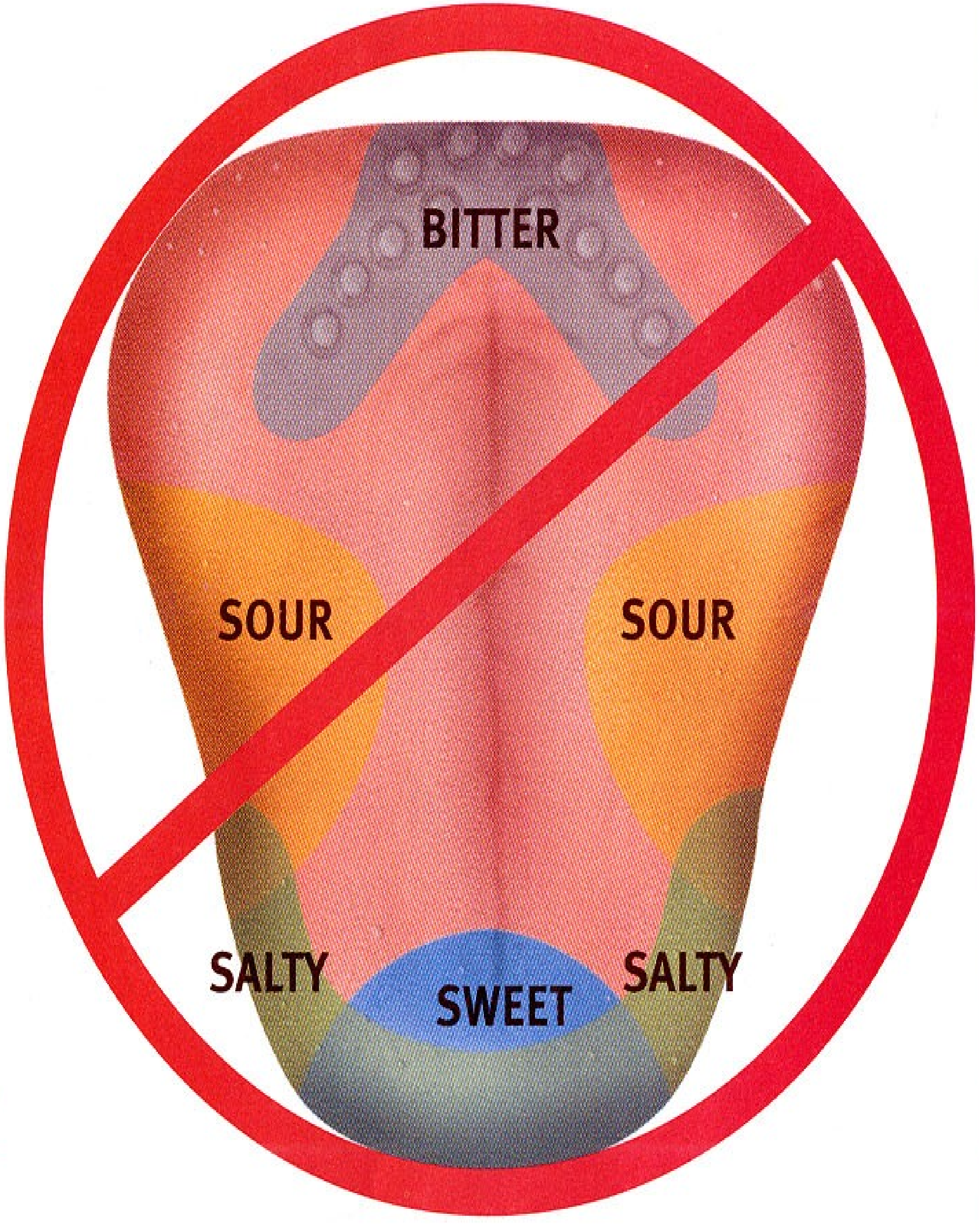
The "Taste Map": All Wrong

One of the most dubious "facts" about taste—and one that is commonly reproduced in textbooks—is the oft-cited but misleading "tongue map" showing large regional differences in sensitivity across the human tongue. These maps indicate that sweetness is detected by taste buds on the tip of the tongue, sourness on the sides, bitterness at the back and saltiness along the edges.

Taste researchers have known for many years that these tongue maps are wrong. The maps arose early in the 20th century as a result of a misinterpretation of research reported in the late 1800s, and they have been almost impossible to purge from the literature.

In reality, all qualities of taste can be elicited from all the regions of the tongue that contain taste buds. At present, we have no evidence that any kind of spatial segregation of sensitivities contributes to the neural representation of taste quality, although there are some slight differences in sensitivity across the tongue and palate, especially in rodents.

—D.V.S. and R.F.M.



OUTDATED "TONGUE MAP" has continued to appear in textbooks even though it was based on a misinterpretation of research done in the 19th century.

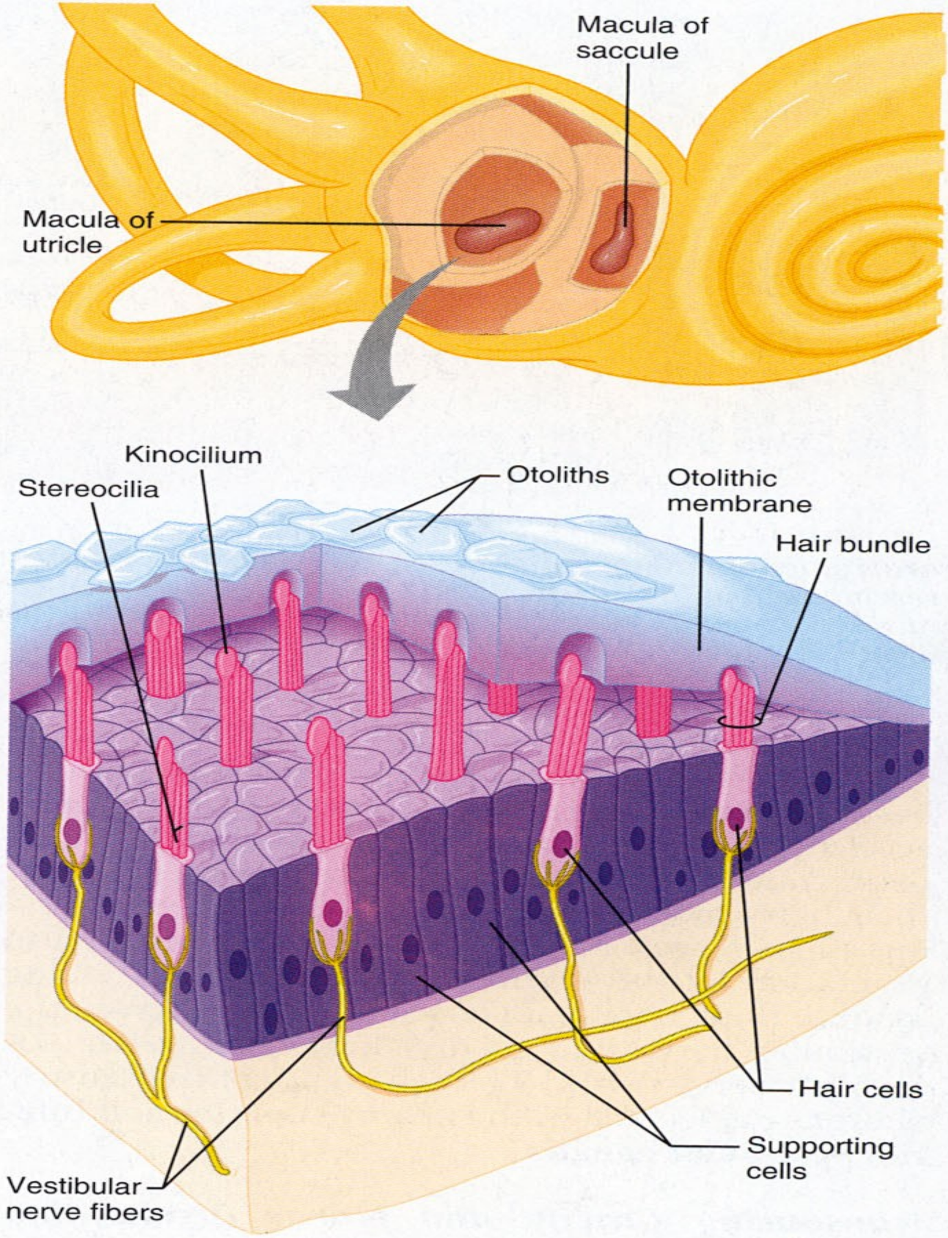


FIGURE 16.34 ***Structure and function of a macula.*** The "hairs" of the receptor cells of a macula project into the gelatinous otolithic membrane. Vestibular nerve fibers surround the base of the hair cells.